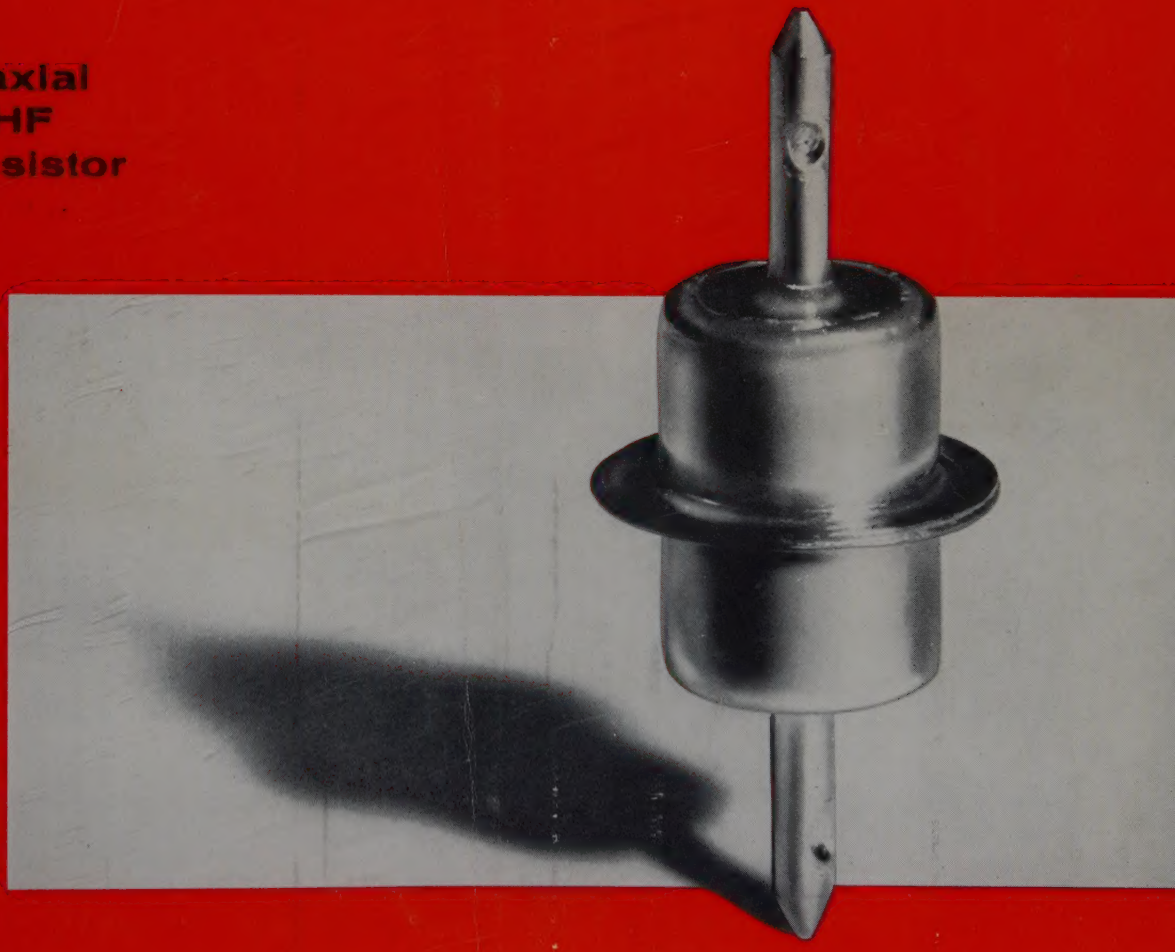
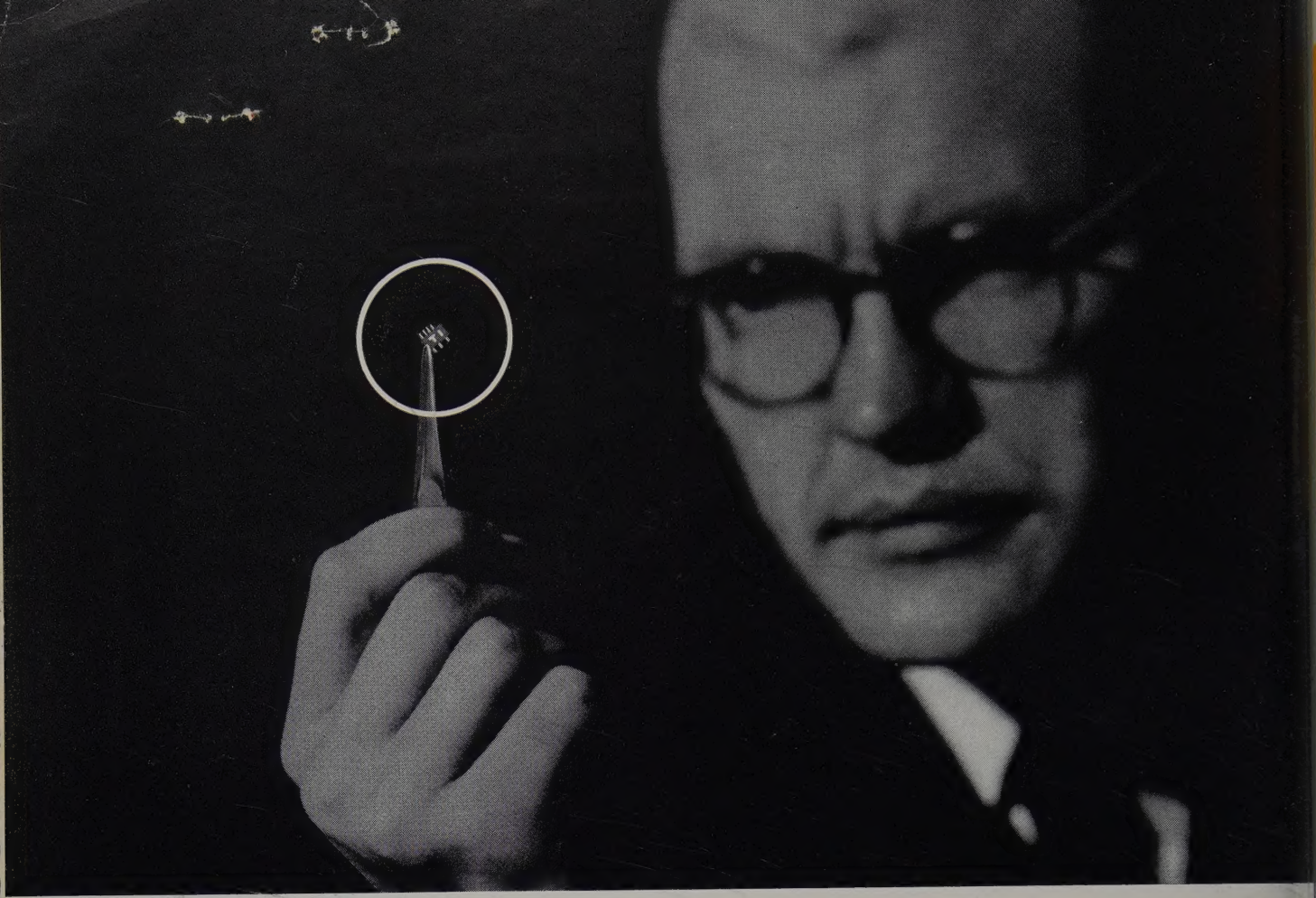
July 1959 75¢

EMICONDUCTOR PRODUCTS

Coaxial
UHF
Transistor

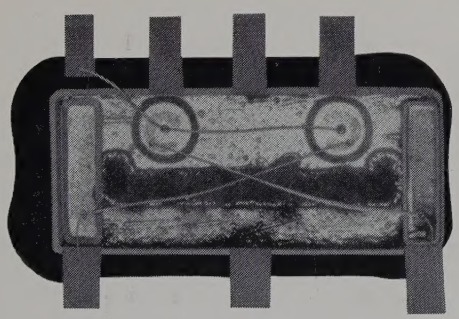


New Configurations in Non-Saturating Complementary Current Switching Circuits • Measurement of Thermal Resistance • Effect of Emitter Bypass Capacitance on Frequency Response.



TI Semiconductor Solid Circuitry...
30,000,000 components per cubic foot!

ACTUAL SIZE: 1/4" x 1/8" x 1/32"



The Semiconductor Solid Circuit shown above is a complete multivibrator containing two diffused-base transistors, two capacitors, and eight resistors... all formed from a single silicon wafer!

A new order of electronic miniaturization has been achieved with TI Semiconductor Solid Circuits. These new solid circuits will enable missiles, satellites, space vehicles, and computers to be built within a new magnitude of miniaturization, while greatly enhancing systems reliability.

Production of Semiconductor Solid Circuits follows process steps similar to those of diffused-base germanium and silicon transistors now being mass produced by TI for military and commercial users. Through the selection and shaping of conduction paths upon and through single-crystal semiconductor wafers by diffusion, metallic evaporation and similar processes, TI produces basic electronic functions such as amplification, oscillation, counting, and switching.

Only advanced facilities can produce advanced components.

The advancement and realization of the Semiconductor Solid Circuit concept by Texas Instruments evolved from a broad background of semiconductor materials and processes. This trend of developments indicates the bold, forward thinking of TI scientists that brings you semiconductors and other components of unsurpassed performance and reliability.

Write on your company letterhead for new Semiconductor Solid Circuit brochure.

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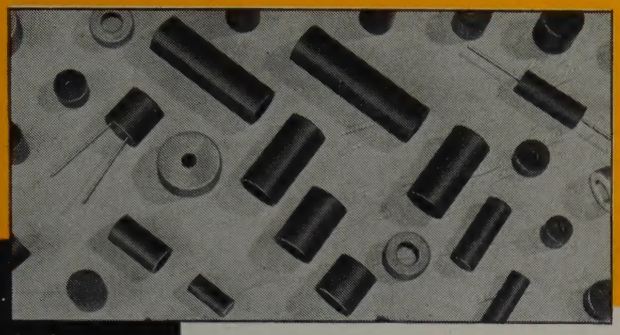
REVOLUTIONIZE YOUR ENCAPSULATION PROCEDURES



The prescribed technique for encapsulating components, using "E-CASES" and "E-FORMS":

UNTIL TODAY . . .

The trouble of tedious mixing and measuring of hardener and resin, the danger of toxicity, the waste of material due to the instability of the compound . . . all of these factors combined, make epoxy encapsulation an extremely inefficient operation.

NOW . . .

A dry, stable, non-toxic pellet of preformed, premixed Epoxy compounds, tailored to your exact requirements, can make encapsulation one of the simplest operations in your manufacturing process.

Developed by Epoxy Products' experienced staff of plasticists, these pellets, though designed primarily for use in conjunction with Epoxy "E-CASE" Shells, are being widely used wherever epoxy resins are required for bonding, sealing or encapsulation.

The "E-FORM" pellet and electronic component are inserted into the "E-CASE", in that order. The assembly is then subjected to heat, with a gentle pressure exerted on the component. The heat causes the pellet to liquefy and flow around the component. Further heating gels and then cures the epoxy. The result is a completely epoxy-encased unit, resistant to humidity, temperature variations and corrosive influences.

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"E-CASES" plus "E-FORM" pellets make **mass production** and **automation techniques** feasible since these combinations can be automatically fed, positioned and assembled with the use of standard available machinery.

Pat. Appl. For

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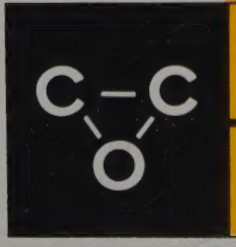

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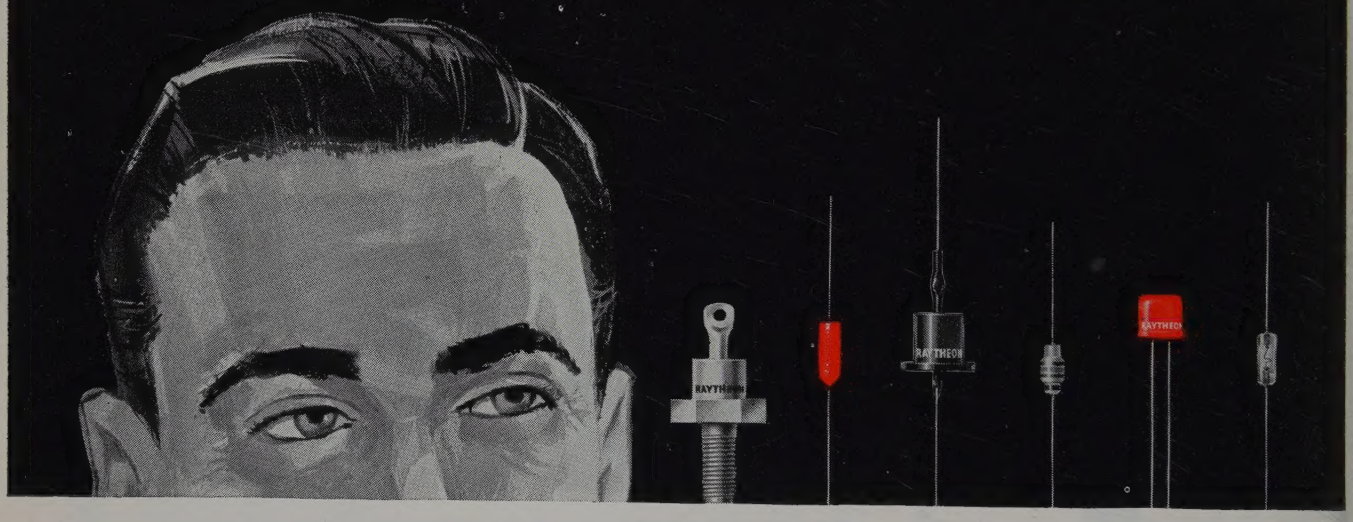

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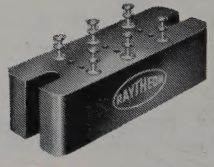

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July 1959 Vol. 2 No. 7

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Editorial 13

New Configurations In Non-Saturating Complementary Current Switching Circuits, by *Carl M. Campbell, Jr.* 15

The Measurement of Thermal Resistance; A Recommendation For Standardization, by *Robert F. Gates and Richard A. Johnson* 21

Effect of Emitter Bypass Capacitance On Frequency Response Of a Grounded-Emitter Transistor Amplifier Stage, by *Thomas R. Hoffman* 27

New Solutions to the Diffusion Equation, by *Worden Waring* 29

Semiconductor Circuit Design Award Rules 26

Applications Engineering Digests 35

Semiconductor and Solid State Bibliography 37

Patent Review 41

Characteristics Charts of Diodes (Cont. from June issue) 44

Characteristics Charts of New Transistors 50

Departments

- New Products 45
- Book Reviews 46
- Industry News 47
- New Literature 60
- Personnel Notes 62

Advertisers' Index 64

Front Cover

Illustrates a transistor with a maximum frequency of oscillation of 3000 *mc*. This product represents progress of continued research in the field of high frequency bipolar transistors by Philco. Contained in a co-axial package with holder matched for direct insertion into a 50 ohm co-axial network, this new "MADT" germanium transistor exhibits a power gain of 9.8 db at 1,000 *mc*. At 200 *mc* (television range), the unit provides a gain of 22 db with a 4 db noise figure, a fact of potential commercial significance.

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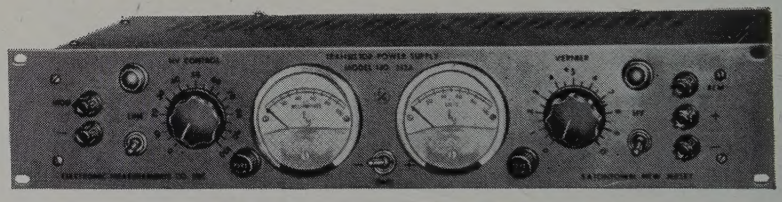
(Various models without the programming feature are also available in voltage ranges up to 1000 V and currents up to 1 ampere.)



TRANSISTOR TYPES

MODEL NUMBER	OUTPUT		REGULATION				MAXIMUM RIPPLE IN MV
			LINE 105—125 V AC 50—60 CPS		NO LOAD TO FULL LOAD		
	Voltage	Current	%	V	%	V	
212A[1]	0—100 V DC	0—100 MA	0.15	0.05	0.1	0.05	½
2-212A[1]	EQUIVALENT TO TWO MODEL 212A's. OUTPUTS MAY BE USED IN SERIES, PARALLEL, OR INDEPENDENTLY.						
224A[1]	0—100 V DC	0—200 MA	0.15	0.05	0.1	0.05	1
220A	0—50 V DC	0—500 MA	0.1	0.05	0.1	0.05	1
221A	0—100 V DC	0—500 MA	0.1	0.05	0.1	0.05	1
213A	0—50 V DC	0—1 AMP	0.1	0.05	0.1	0.05	1
214A	0—100 V DC	0—1 AMP	0.1	0.05	0.1	0.05	1
215A	0—50 V DC	0—3 AMP	0.1	0.05	0.1	0.05	1
218A	0—100 V DC	0—3 AMP	0.1	0.05	0.1	0.05	1

1. Modulation input provided for measurement of transistor parameters by small signal method.

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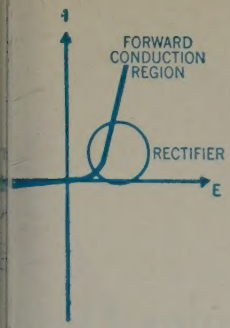

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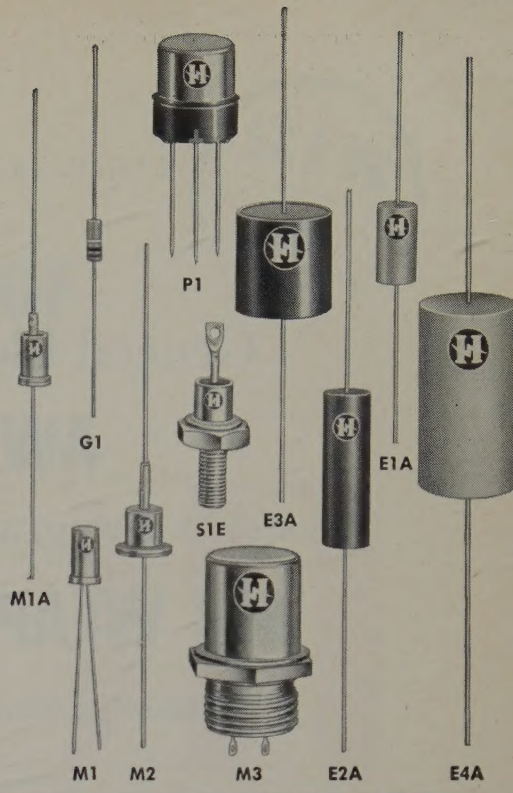

	6 ZENER LOW VOLTAGE DIODES • 200mW • Zener Voltage Range: 2.0V — 8.0V	6 ZENER MICRO-MINIATURE GLASS LOW VOLTAGE DIODES • 250mw • Zener Voltage Range: 2.0V — 8.0V	5 ZENER "DOUBLE ANODE" LOW VOLTAGE DIODES • 200mW • Zener Voltage Range: 3.0V — 8.0V	15 ZENER "SINGLE ANODE" MEDIUM VOLTAGE DIODES • 150mW • Zener Voltage Range: 7.5V — 145V	9 ZENER "DOUBLE ANODE" MEDIUM VOLTAGE DIODES • 150mW • Zener Voltage Range: 7.5V — 45V	6 ZENER REFERENCE DIODES & ELEMENTS • Operating Zener Voltage: IN429:6.2V ±5% 1N430, 1N430A, 1N430B, 1N1530, 1N1530A: 8.4V ±5% • Dyn. Imp.: 1N429:20 ohms Others: 15 ohms	4 ZENER REFERENCE MICRO-MINIATURE DIODES • Operating Zener Voltage: 5.9V to 6.5V • Dyn. Imp.: 15 ohms	15 ZENER REFERENCE STRINGS • Operating Zener Voltage: 6.2V thru 49.6V ±5% • Dyn. Imp.: 20 ohms to 180 ohms (over the entire line)	38 ZENER VOLTAGE REGULATORS 10 WATT • Zener Voltage Range: 5.6V to 200V ±10% • Dyn. Imp.: 1 ohm to 140 ohms (over the entire line)	38 ZENER VOLTAGE REGULATORS 1 WATT • Zener Voltage Range: 5.6V to 200V ±10% • Dyn. Imp.: 1.2 ohms to 1100 ohms (over the entire line)	38 ZENER VOLTAGE REGULATO 1/4 WATT • Zener Volta Range: 5.6V 200V ±10% • Dyn. Imp.: 3.5 ohms to 1400 ohms
Case Type	M1	G1	M1	M1	M1	M1, M3, P1	G1	E1A, E2A, E3A, E4A	S1E	M1A	G1

	26 GENERAL PURPOSE SILICON DIODES • 150mW • PIV Range: 6.8V thru 470V	6 HB GENERAL PURPOSE SILICON DIODES • 150mW • PIV Range: 6.8V thru 270V	8 GLASS GENERAL PURPOSE DIODES • 200mW • PIV Range: 25V to 175V	5 GLASS FAST RECOVERY SILICON DIODES • 200mW • PIV Range: 25V to 175V
Case Type	M1	M1	G1	G1

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Case Type	M1A	M2	S1E

9 SILICON SOLAR CELLS
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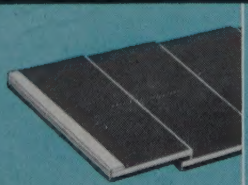
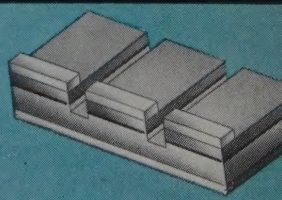


8 PHOTO-VOLTAIC READOUT CELLS
• Number of readout positions: from 4 to 10
• Spectral Response: Range: 4000 to 11,500 angstroms; Peak: 8500 angstroms



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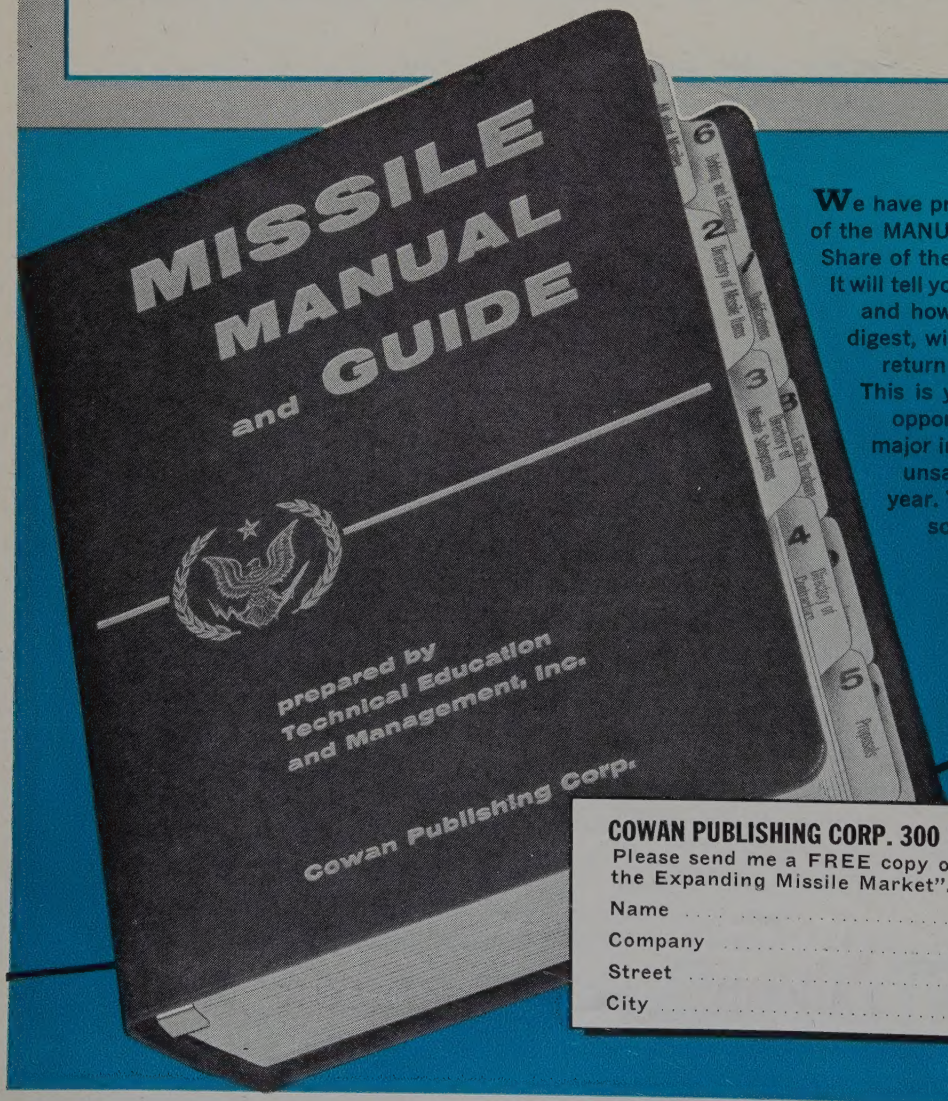

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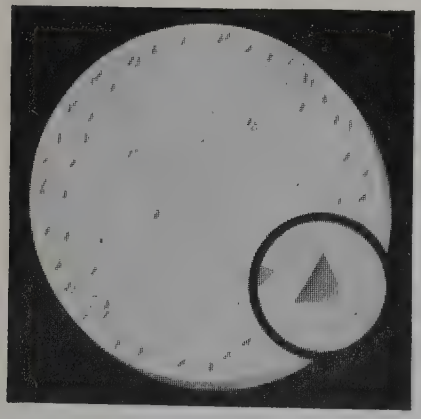

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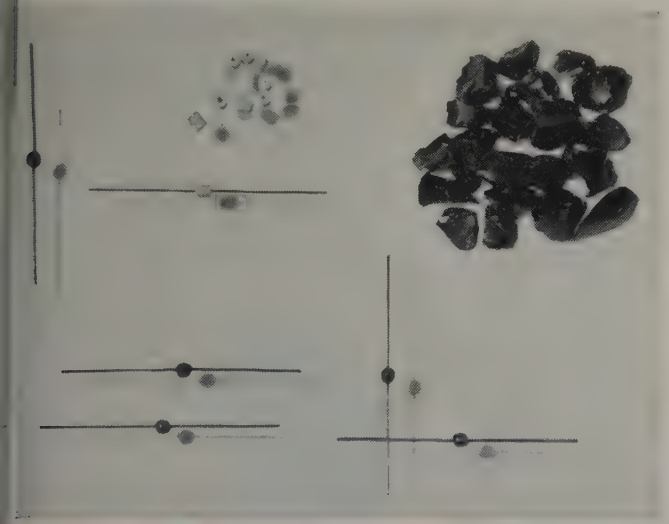

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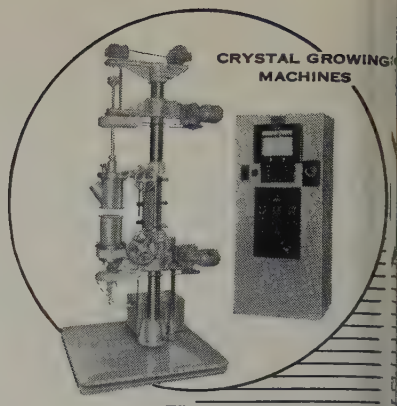
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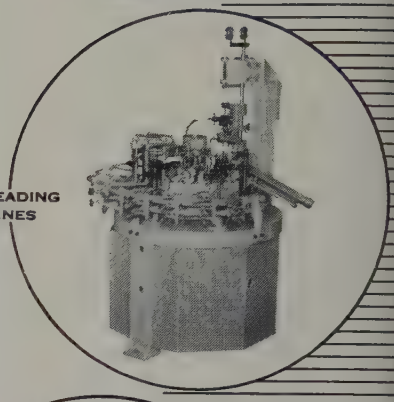
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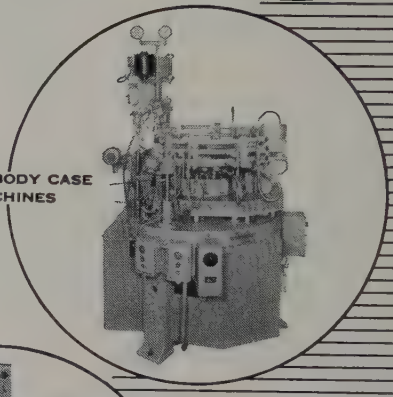
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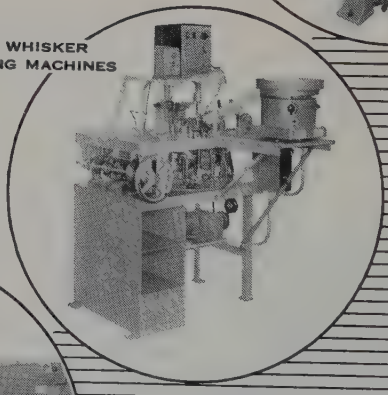
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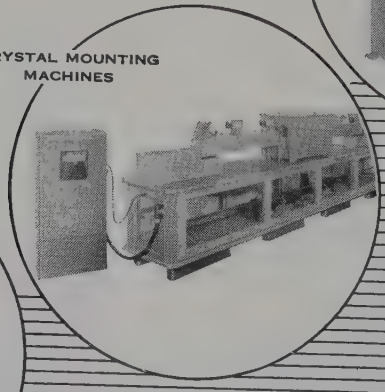
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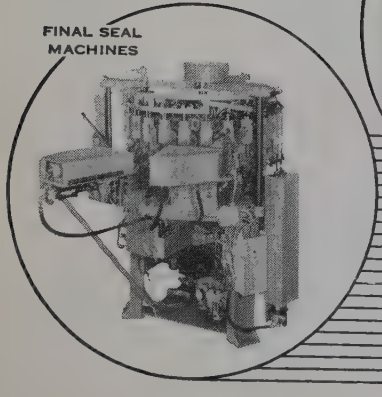
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Editorial . . .

Avalanche Effects In Transistors

The avalanche nature of breakdown phenomena in p-n junctions has been discussed previously in these pages (see Editorial March 1958 by Dr. W. Shockley). The phenomenon is becoming increasingly important for such technical applications as the generation of very high current pulses, the design of bistable, monostable and astable circuits, etc. For these reasons it is desirable that the properties of avalanche transistors be controlled at the designer stage. The main parameters of interest are the breakdown voltage V_B and the sustain voltage V_c^*. The breakdown voltage is the value of V_{cb} for which the current amplification factor α_{ce} becomes infinite, i.e. $I_e = 0$, $I_b = -I_c$, $\alpha_{cb} = -1$; the sustain voltage is the value of V_{cb} for which the current amplification factor α_{cb} becomes infinite, i.e. $I_b = 0$, $I_e = -I_c$, $\alpha_{ce} = -1$. The common emitter operated in the range $|V_c^*| < |V_{cb}| < |V_B|$ possesses a non-inverting voltage gain and a current gain larger than unity. Hence it may be made unstable by use of positive feedback, and in such condition it presents open circuit stable negative resistances at the emitter and at the collector terminals, and short circuit stable negative resistance at the base terminal. Utilizing such characteristics it is possible to construct various unstable circuits such as relaxation oscillators, blocking oscillators, flip-flops, etc. To increase the voltage excursion, the difference $V_B - V_c^*$ should be made as large as possible, while at the same time the breakdown voltage V_B should be made small. The value of V_B depends upon the base resistivity with the empirical relationship $V_B \cong 84\ \rho_b^x$ where $x \cong 0.63$ for n-type germanium; hence the base resistivity of avalanche transistors is generally lower than usual. The sustain voltage may be decreased making the value of the current amplification factor α_{ce} at low voltage as close to one as possible, and furthermore using semiconductors with low multiplication exponent; the value of V_c^* is approximately given by the relation $V_c^* = V_B\ (1 - \alpha_{ceo})^{1/n}$ where n is the multiplication exponent. Finally in order to improve the rise time of the collector output the collector capacitance as well as the base width should be made as small as possible. As an example practical values of V_B of the order of 20 V and V_c^* of the order of 8 V have been obtained, with rise times at the collector output of the order of 10^{-9} to 10^{-7} sec.

The International Convention on Transistors and Associated Semiconductor Devices

The Proceedings of the International Convention on Transistors and Associated Semiconductor Devices held at Earl's Court Exhibition hall; London, England on the 21-27 May 1959 will take its place beside the two previous publications of the American Proceedings of the I.R.E., November, 1952 and June, 1958. At the Convention, which attracted 2,000 scientific personnel including 400 foreign visitors, over 150 technical papers were presented covering generally five different areas of the semiconductor field. Listed below are these areas and the number of sessions devoted to each.

1) Materials—two sessions
2) Basic Theory—two sessions
3) Technology and Design and Manufacture—four sessions
4) Characteristic Measurements, and Transistors as a Circuit Element—five sessions
5) Applications—nine sessions

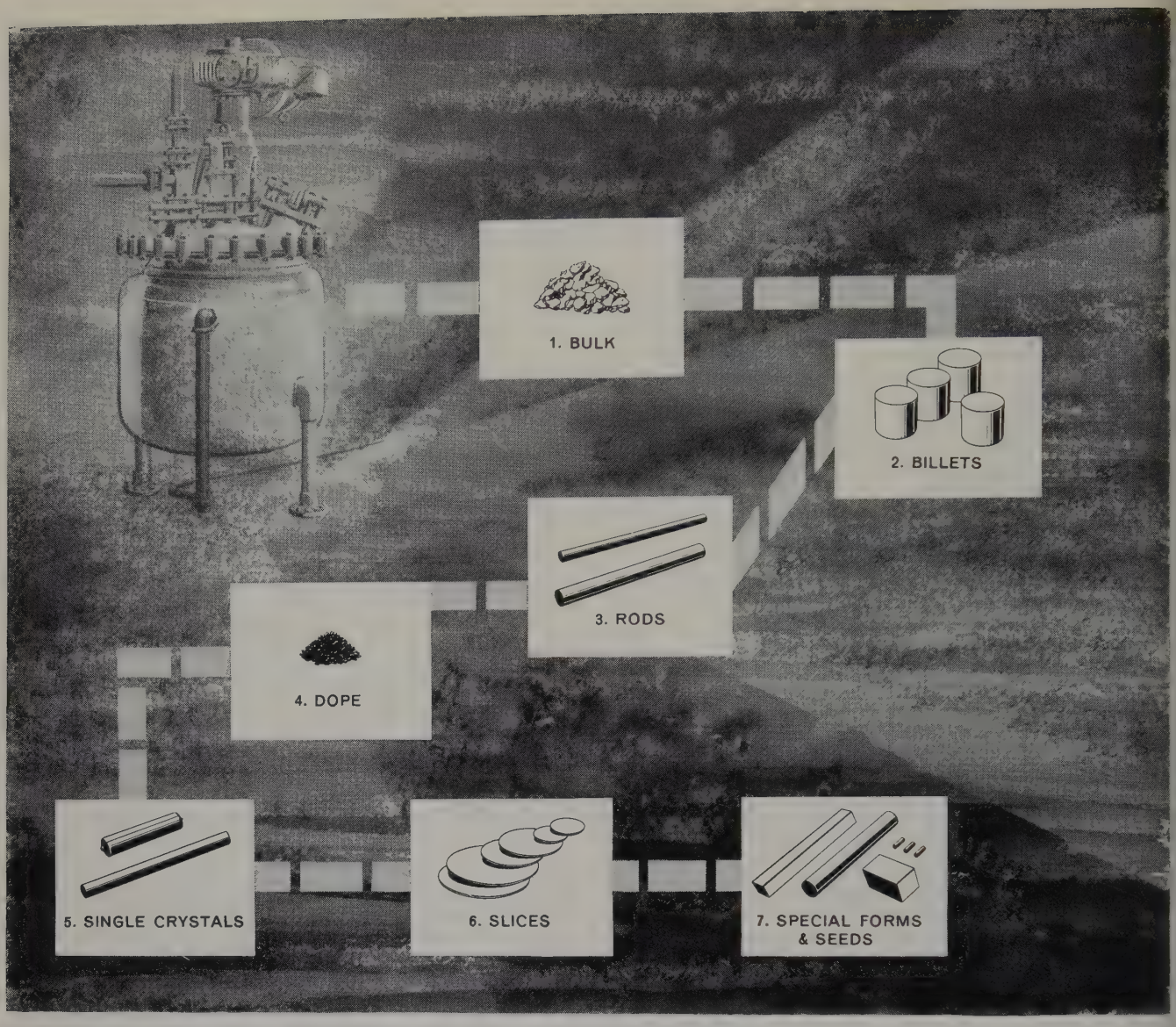
Emphasis on papers which were presented covered the following subjects: Switching Communications, Linear Amplifiers and Oscillators, and Industrial Applications. The Convention provided the members of the Industry with a summation of the field.

In conjunction with the Convention the Exhibition, unique in nature because of its complete devotion to the industry, provided the viewer with more practical aspects. The scope of the exhibition encompassed transistors and other semiconductor devices, materials used in transistor manufacture, equipment incorporating semiconductor devices and specialized components used in transistorized equipment. The Exhibition was technical in nature with exhibitors from eight different countries participating including: U.S.A., Great Britain, Germany, France, Japan, Italy, Belgium and Austria.

In the United Kingdom alone there are 19 companies which are or are about to manufacture the newer classes of semiconductor devices. These exclude copper, oxide and selenium devices. Amongst this group 611 product types are offered, made up of 149 transistors, 207 diodes, 234 rectifiers and 21 photosensitive devices.

A subsequent issue of SCP will present a more complete resumé of the conference.

Samuel L. Marshall



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New Configurations In Non-Saturating Complementary Current Switching Circuits

CARL M. CAMPBELL, JR.*

Complementary current switching circuits are becoming well known in the present state of the digital computer art. They are especially valuable for high-speed applications because not only are they non-saturating, but they may also be operated as far out of the saturation region as is desired. In addition, they are simple, reliable and relatively noise insensitive. A new technique has been devised which is an addition to the current switching art. This, the inhibit technique, when combined with the conventional current switching techniques gives great flexibility to the circuit designer and makes possible many new and interesting circuit configurations. Many of these require fewer components than equivalent circuits formed entirely from the conventional techniques.

THE INNOVATION of the "inhibit" technique has resulted in increased flexibility in circuit design, and in a wide variety of new and useful circuit configurations. It is the purpose of this article to explain the "inhibit" principle and to describe some typical circuits in which the principle is utilized. In the interest of clarity and continuity, the basic conventional current switching techniques will be dealt with first.

Basic Current Switching Circuits

In *Fig. 1* are shown the *p-n-p* and the *n-p-n* switches, which form the basis of all complementary current-switching circuits. The operation of the *p-n-p* switch is as follows:

The resistor *R1* to plus 36 volts forms an approximately constant current source. This constant current flows through whichever transistor has the more negative base potential. Let us assume that the base of *T1* is at plus 3 volts. This causes *T1* to conduct and causes its emitter, point *"B"* to become approximately plus 3¼ volts. Since the base of *T2* is at plus 4 volts and its emitter at plus 3¼ volts, it is biased *off*. Thus the entire constant current flows through *T1*. Except for a small loss to the base circuit, this current flows into the collector and brings point "C" to a value somewhat more positive than minus three volts. The potential to which it goes cannot be determined exactly as it depends upon the *d-c* beta of the transistor, the tolerance of resistors and power supplies, and upon the amount of load current being drawn from point *C*. Since *T2* is biased off, no current flows into its collector resistor, and point *D* is at minus 5 volts.

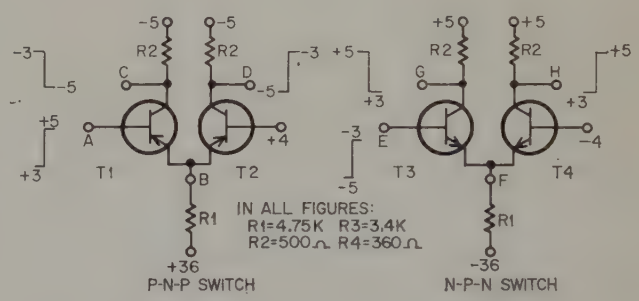

Fig. 1—Complementary current switches.

Now let us assume that point *A* changes to plus 5 volts. *T2* conducts and point *B* becomes approximately plus 4¼ volts, thus back-biasing. *T1*. Since *T2* is conducting, its collector, point *D*, becomes somewhat more positive than minus three. Since *T1* is cut off, point *C* becomes minus 5 volts.

Thus we have seen that as point *A* varies around plus 4 volts, the entire constant current switches between *T1* and *T2*. We can also see that the outputs as taken at *C* and *D* are always logically the inverse of each other. Finally, we see that by the proper choice of values, the transistors may be operated as far out of saturation as desired.

The operation of the *n-p-n* switch is the same as that of the *p-n-p*, except that all polarities are reversed.

It is apparent that the output of one switch, as taken on either collector, cannot be directly coupled to the input of another switch of the same type because of the voltage shift inherent within the device. However,

*Burroughs Corporation Research Center, Paoli, Pennsylvania

it is possible to directly couple the output of a *p-n-p* switch to the input of an *n-p-n* switch, and vice-versa. That this is so can be clearly seen by comparing the various output and input levels as illustrated in *Fig. 1*. Therefore, it is necessary always to drive an *n-p-n* input from a *p-n-p* output, and a *p-n-p* input from an *n-p-n;* hence the name "complementary current switching circuits." Of course it is possible to use only one type of transistor if some sort of level-shifting device is used between the output of one switch and the input of the next. Since such a system involves design complications, we will limit ourselves to the simpler complementary system in this article.

These complementary circuits may be "*d-c* worst case designed" for steady-state conditions. By "*d-c* worst case design" is meant that design technique whereby, to the value of each circuit component is assigned a tolerance within which it is certain its value will fall under all anticipated conditions. The circuit is then designed so that under all possible steady-state conditions the circuit will operate even though every component should be at that limit of its tolerance which tends to cause circuit failure.

All circuits presented in this article have been designed with this philosophy to help insure their reliability.

Turning now to *Fig. 2*, we see a simplification which may often be made in the *n-p-n* or the *p-n-p* switch. As we saw in *Fig. 1*, the basic switch gives two outputs, one of which is the logical inverse of the other. Cases often arise in which it is not necessary to utilize the outputs *D* or *H*, taken on the collector of the transistor with the biased base. Under these conditions, this transistor may be replaced by a diode, as illustrated in *Fig. 2*. Considering the *p-n-p* switch, if point *A* is more negative than plus 4 volts, its emitter, point *B* will become more negative than plus 4 volts thus back-biasing the diode. Thus the entire constant current will flow through the transistor bringing point *C* somewhat more positive than minus 3 volts. However, if point *A* is more positive than plus 4 volts, the constant current will flow through the diode, and point *B* will become plus 4 volts thus biasing off the transistor and causing point *C* to become minus 5 volts.

Gates may easily be formed from the basic switch by putting more transistors in parallel with the input transistor. This is illustrated by the *p-n-p* gate of *Fig. 3*. If point *A*, *B*, or *C* is at plus 3 volts, (or more negative) *T1*, *T2*, or *T3* will conduct, and *T4* will be biased off, thus causing point *D* to become minus 3 volts (or more positive) while point *E* becomes minus 5 volts. If points *A*, *B*, and *C* are all at plus 5 volts, *T1*, *T2*, and *T3* will be off and *T4* on, thus causing point *D* to become minus 5 volts, and point *E* minus 3 volts (or more positive). Therefore, we see that if a plus 3 volt input is considered as a "*one*," this circuit is an "*or*" gate, while if a plus 5 volt input is a "*one*," it is an "*and*" gate. Of course a similar circuit can be constructed using *n-p-n* transistors.

The Inhibit Principle

All that has been presented so far has been previously known and publicized and has been presented merely as a background information. We shall now take up the inhibit principle with its applications.

In *Fig. 4*, we see a conventional *n-p-n* switch and a *p-n-p* switch with the collector of one of its transistors connected directly to the emitter junction of the *n-p-n* switch. As long as the *p-n-p* in question, *T2*, does not conduct, the *n-p-n* switch will function normally, the output levels at *D* and *E* being determined by the input level at *C*. *T2* will remain non-conductive as long as point *A* is more negative than plus 4 volts thus causing *T1* to conduct and *T2* to be biased off. Now let us suppose that point *A* becomes more positive than plus 4 volts. *T1* will now cut off, and *T2* will conduct. The entire collector current from *T2* will now flow into *R1*. By making *R3* sufficiently smaller than *R1*, it can be assured that point *B* will become more positive than the most positive potential that can ever occur on either *n-p-n* base. Thus both *T3* and *T4* will be back biased, and points *D* and *E* will both be at plus 5 volts regardless of the input at *C*. Therefore, the *n-p-n* switch will be "inhibited."

If a "*d-c* worst case design" philosophy is used, it is necessary to include the diode to assure that *T2* will never saturate. Without the diode, it would be possible under extreme conditions for point *B* to become more positive than plus 4 volts. With the diode, point *B* cannot go more positive than ground. This is sufficiently positive to assure that *T3* will be back biased for any possible value of input at *C* but sufficiently negative to assure that *T2* can never saturate. If a nominal, rather than worst case, design is used, the diode may often be omitted. For this reason, it is shown connected by dotted lines.

New Circuit Configurations Made Possible By The Inhibit Principle

One of the best examples of how the inhibit technique may be utilized, is the half adder of *Fig. 5*. We have here two *n-p-n* switches inhibited by a *p-n-p* switch. The two *n-p-n* inputs marked *B*, are connected together to form one of the inputs to the half-adder. The other input is at *A* the base of *p-n-p T2*. Let us assume that "0" is present at both *A* and *B*. As indicated, this will mean that a minus 5 volt level will be present at *B*, and a plus 5 volt level at *A*. Because of the level at *A*, *T2* will be *off*, and *T1 on*. Because of the conduction of *T1*, the lefthand *n-p-n* switch will be inhibited, and both *T3* and *T4* biased *off*. Since *T3* is *off*, the level at the *CARRY* output will be plus 5 volts, which corresponds to a "0". Since *B* is assumed at minus 5 volts, *T5* will be biased *off*, and the diode to minus 4 volts will be conducting. Since both *T4* and *T5* are biased *off*, no current will flow into *R2* so that the *SUM* output will be at minus 5 volts, and hence a "0".

Now let us assume that the level at *B* changes and becomes minus 3 volts (or more negative), thus corresponding to a "1" at this point, while the signal at *A* remains unchanged. Since *A* is unchanged, *T1* remains *on* and *T2 off*. As before, *T3* and *T4* are inhibited and the *CARRY* output is at +5 volts ("0"). Now, however, since the base of *T5* is more positive than minus 4 volts, *T5* will conduct thus bringing its collector to approximately plus 3 volts. This corresponds to a *SUM* of "1", which is clearly correct for inputs of "0" and "1".

Now we assume point *B* is at minus 5 volts ("0"), and point *A* is more negative than plus 3 volts ("1"). *T2* is now conducting, and *T1* off. *T5* is inhibited by the conduction of *T2*. Because of the input at *B*, *T4* will conduct and *T3* will be *off*. Since *T3* is *off*, the *CARRY* output is at plus 5 volts, and hence a "0". Since *T4* conducts, current will flow into the right-hand *R2* causing the *SUM* voltage level to become more negative than plus three volts, thus corresponding to a "1". A *SUM* of "1" and a *CARRY* of "0" are clearly correct for inputs of "1" and "0".

Finally, let us assume that input *A* is at plus 3 volts and input *B* at minus 3 volts, corresponding to a "1" at both inputs. Since *T2* conducts, *T5* is inhibited. Because of the minus 3 volt level present at *B*, *T3* will be *on*, and *T4 off*. The conduction of *T3* causes the *CARRY* output to become more negative than plus 3 volts, thus corresponding to a "1" output at this point. Since both *T4* and *T5* are *off*, there is no current flow into the right-hand *R2* resistor, so the *SUM* output is at plus 5 volts indicating a "0". Thus we have a *SUM* of "0" and a *CARRY* of "1", which is the correct result for inputs of "1" and "1".

It will be noted that the collectors of *T4* and *T5* are both fed into the same resistor. This is a form of "*or*" gate, in that the conduction of *T4* or *T5* will cause the flow of current through the resistor. For this configuration, it will be impossible to have both *T4* and *T5* conducting as a steady-state condition. Therefore, neither transistor will saturate, since no more than about 7 *ma* will ever flow through the resistors.

In the example we have considered, we have biased the base of *T1* and applied the *A* input to the base of *T2*. It would be possible, instead, to bias the base of *T2*, and apply the signal to the base of *T1*. Now, however, a "1" would be represented by a plus 5 volt level and a "0" by a plus 3 volt level. Therefore, if the circuit which drives the half-adder gives a "1" when its output gives a plus 3 signal, the input is applied as shown. However, if the driving circuit gives a "1" when it gives a plus 5 volt signal, the arrangement just described is used. This flexibility is often useful.

In addition, transistors may be placed in parallel with the input transistors to provide gating action. Thus, if the input is applied to the base of *T2*, as shown, and other transistors are put in parallel with it, the conduction of any one of these transistors will inhibit *T5* and cut off *T1*. Thus the effect is that of an "*or*" gate. If the signal is applied to the base of *T1*

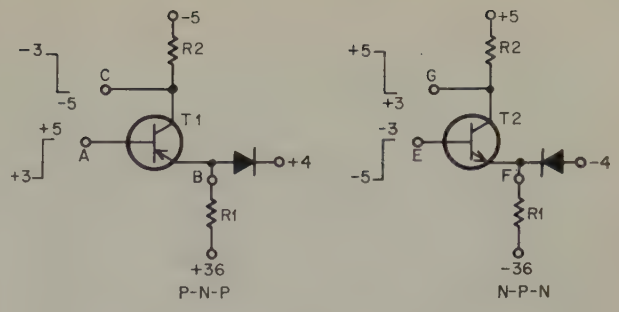

Fig. 2—Simplified current switches.

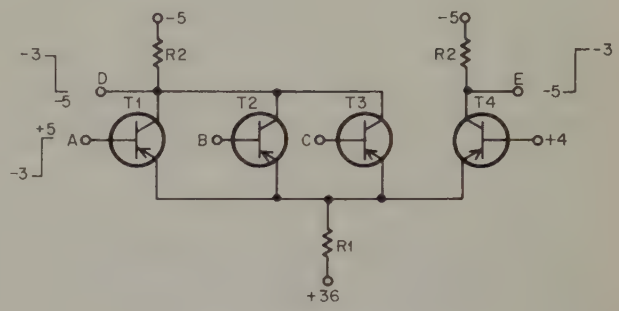

Fig. 3—P-N-P gate circuit.

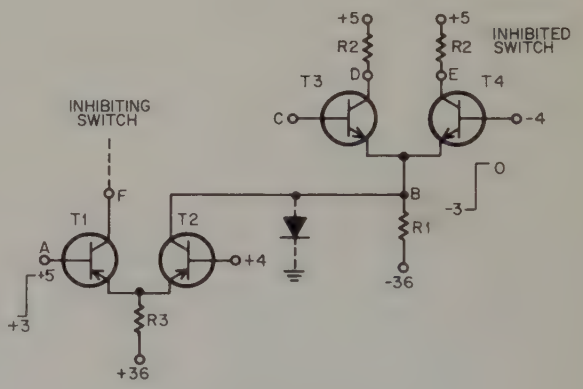

Fig. 4—The "inhibit" circuit.

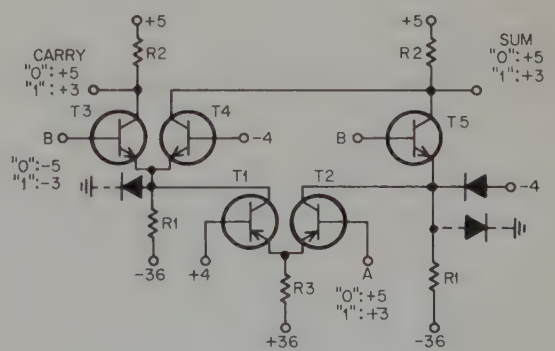

Fig. 5—Half adder circuit.

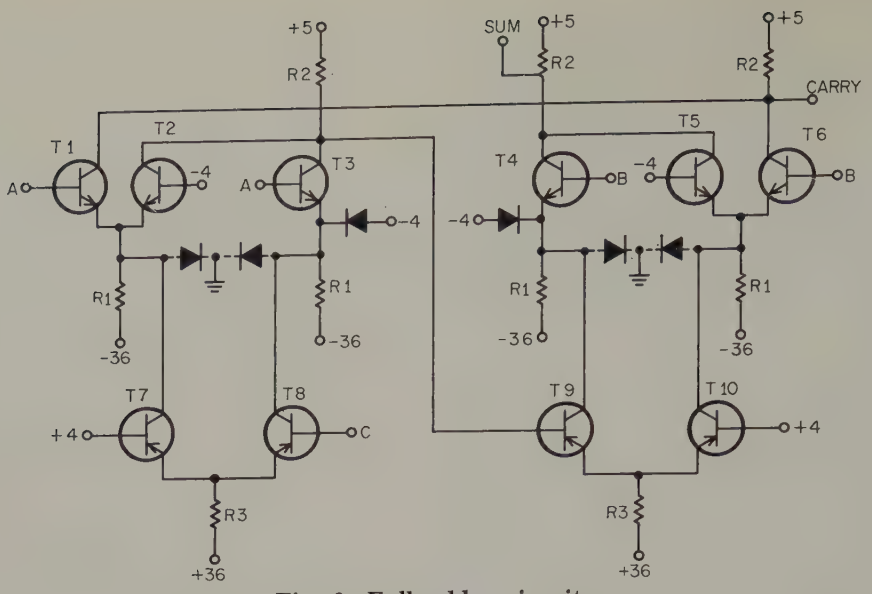

Fig. 6—Full adder circuit.

and other transistors are put in parallel with it, all of them must be *off* in order for *T2* to conduct. Therefore, the effect is that of an "*and*" gate.

In the same manner that the input *A* may be applied either to the base of *T1* or that of *T2*, so may signal *B* be differently applied. By replacing the diode to minus 4 volts by a transistor which we will call *T6*, it is possible to bias the bases of *T3* and *T5*, and apply the signal to the bases of *T4* and *T6*. This has the effect of making the minus 5 volt level correspond to a "1", and the minus 3 volt level to a "0". Gating may also be accomplished at input *B* in much the same way described for input *A*.

It is a well known fact that a full-adder may be formed from two half-adders and an "*or*" gate. *Fig. 6* shows a current switching full-adder constructed in this way. The *SUM* output of one half-adder is fed into the other half-adder. The output of a half-adder has the proper swing to feed the *A* input of another half-adder. The *CARRY* outputs of the two half-adders must be "*ored*" together. In this case, this may be easily accomplished by connecting the two appropriate transistor collectors to a common resistor. The three inputs to the full-adder are *A*, *B*, and *C*, as shown. A detailed description of the circuit's operation is not given as it can be well understood from the operation of the half-adder.

The inhibit principle may be adapted to form a flip-flop, as illustrated in *Fig. 7*. The operation of the circuit is as follows:

Normally, the voltage levels present on the *SET* and *RESET* points are minus 3 volts, or more positive, so that transistors *T1* and *T2* are tending to conduct. Let us assume that *T1* is conducting. Therefore, its collector will be at a level more negative than plus 3 volts, causing *T4* to conduct. Since *T4* conducts, *T2* is inhibited and hence *off*, despite the minus 3 volt level on its base. Since *T2* is *off*, its collector is at plus 5 volts, thus assuring that *T3* is *off*. Since *T3* is not conducting, *T1* is able to conduct, as initially assumed. Thus the flip-flop is in one of its two stable states, with *T1* and *T4* conducting, and *T2* and *T3* non-conducting. Now let us assume that a negative pulse is applied to the base of *T1*, so that it momentarily goes to minus 5 volts. Because of the diode to minus 4 volts at its emitter, *T1* will now be back-biased and the diode will conduct. Since *T1* turns *off*, its collector and hence the base of *T4* goes to plus 5 volts. The base of *T3* is already at plus 5 volts. Due to the diode to plus 4 volts on their emitters, both will be back-biased, and the diode will momentarily conduct. Since *T4* is *off*, and since the base of T2 is at minus 3 volts, *T2* will begin to conduct. When this happens, its collector will go to about plus 3 volts. This will now cause *T3* to begin conducting, and the diode to plus 4 volts, as well as *T4*, to be back-biased. Since *T3* is now conducting, *T1* is inhibited, its emitter being at ground potential, so that, even after the *SET* input level returns to minus 3 volts the flip-flop will remain in the state into which it had just been set, with *T1* and *T4* non-conducting, and *T2* and *T3* conducting. Since the circuit is symmetrical, it is clear that a negative reset pulse will momentarily turn off *T2* and cause the flip-flop to return to the state initially assumed.

The basic flip-flop gives outputs capable of driving only *p-n-p* transistors. In most cases, it is possible to arrange the logic so as to have this always true. If, however, it is necessary to have the flip-flop drive *n-p-n* transistors as well, this may be accomplished by modifying the flip-flop as shown in *Fig. 8*. In this modified flip-flop, one stable state has *T1*, *T5*, and *T3* *on*, while *T2*, *T6*, and *T4* are *off*. *T1* and *T2* normally have their bases more positive than minus 3 volts, so they are tending to conduct. Let us assume that, under the condition assumed above, *T1* is momentarily

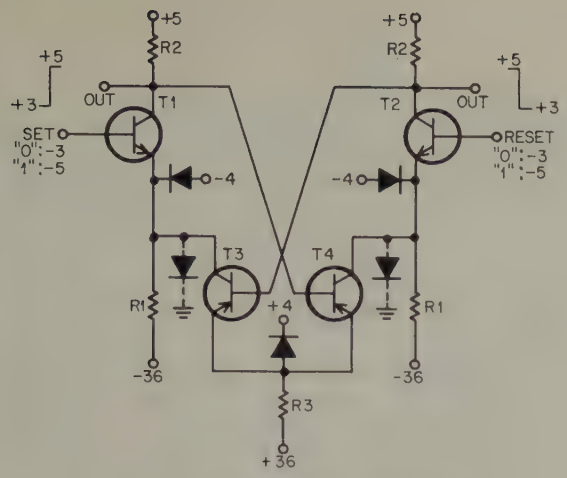

Fig. 7—Basic flip-flop circuit.

cut off by applying a negative pulse to pull its base to minus 5 volts. The turning *off* of *T1* turns *T5 off*, and hence *T6 on*. The non-conduction of *T5* uninhibits *T2*, allowing it to conduct. This, in turn, causes the conduction of *T4* and the non-conduction of *T3*. When *T4* turns *on*, *T1* becomes inhibited so that it will remain *off* even after its base returns to the minus 3 volt level. This flip-flop has outputs on the collectors of *T1* and *T2* which can drive *p-n-p* transistors, and also outputs on the collectors of *T3* and *T6* which can drive *n-p-n* transistors. These latter outputs have the advantage that they are buffered from the internal flip-flop circuitry, so that loading these points has no effect on the switching action of the flip-flop. If an output from the collector of one of these two latter transistors is not required, the transistor in question may be replaced by a diode to plus 4 volts in the manner of *Fig. 2*.

In any practical logic system, it is almost always required to set, and often to reset, flip-flops through *AND* and *OR* gates. It is very desirable to incorporate gates within the flip-flop, as considerable saving in components can be realized by so doing. In many flip-flops it is possible to incorporate *OR* gates, but in this flip-flop it is possible to incorporate both *AND* and *OR* gates. The circuit modifications required for this incorporation are shown in *Fig. 9*. Transistors *T1*, *T2*, *T3*, and *T4* have their bases normally at the minus 3 volt level, so they tend to conduct. Transistors *T5* and *T8* have their bases normally at plus 5 volts and hence are normally *off*. Let us assume a stable state in which *T1* and/or *T2*, and *T7* are conducting, the other transistors being *off*. Suppose now that the base of *T1* goes to minus 5 volts. This will have no effect, as *T2* will take up the conduction. If *T2* now has a minus 5 volt level applied to its base, it will be turned *off*. Since both *T1* and *T2* are *off*, their common collector resistor will have no current flowing through it and will go to plus 5 volts. This will cut off *T7* and uninhibit *T3* and *T4*. These transistors will then conduct and bring their common collectors to the plus 3 volt level. This turns *T6 on*, thus inhibiting *T1* and *T2*. Thus the flip-flop has changed states. To accomplish this, however, required that both *T1* and *T2* be turned *off*. This clearly has the effect of an *AND* gate. The effect described was that of a two input *AND* gate. If more inputs are desired, this may be accomplished by putting still more transistors in parallel with *T1* and *T2*. An *AND* gate effect at the *RESET* may be accomplished in a similar way, as illustrated by *T4* and *T3* in parallel.

Let us again assume the initial condition, as above, with *T1* and/or *T2* and *T7 on*, and the other transistors *off*. Now suppose that the plus 3 volt level is applied to point *E*, the base of *T5*. Since the base of *T6* is at plus 5 volts, and the cathode of the diode at plus 4 volts, the base of *T5* will be the most negative, so that *T5* begins to conduct. This will inhibit *T1* and *T2* thus stopping their conduction. This has the effect of turning off *T7* which causes *T3* and/or *T4* to turn on, thus turning on *T6*, so that the inhibiting effect on *T1* and *T2* will continue even after point *E* returns to plus 5 volts. Thus the flip-flop has changed states. Therefore, the flip-flop may be "set" either by applying simultaneous signals at *A* and *B*, or by applying a signal at *E*. This, clearly, is an *OR* gate effect. To have more

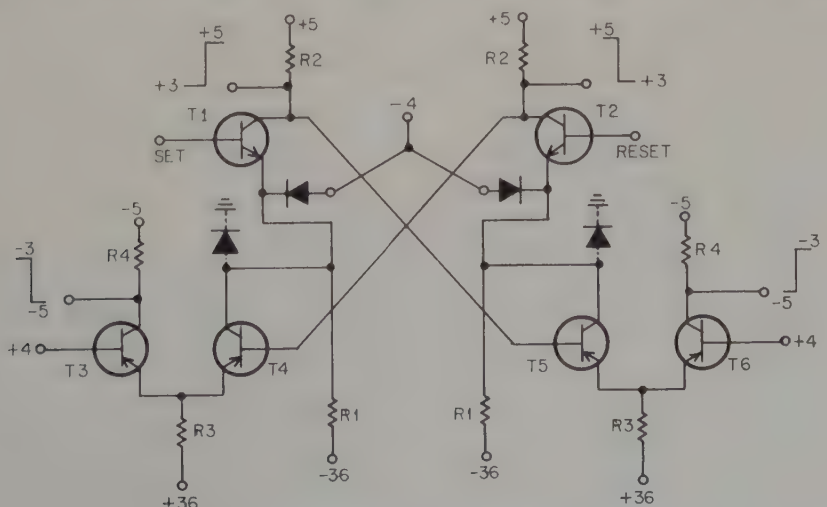

Fig. 8—Flip-flop with four output levels.

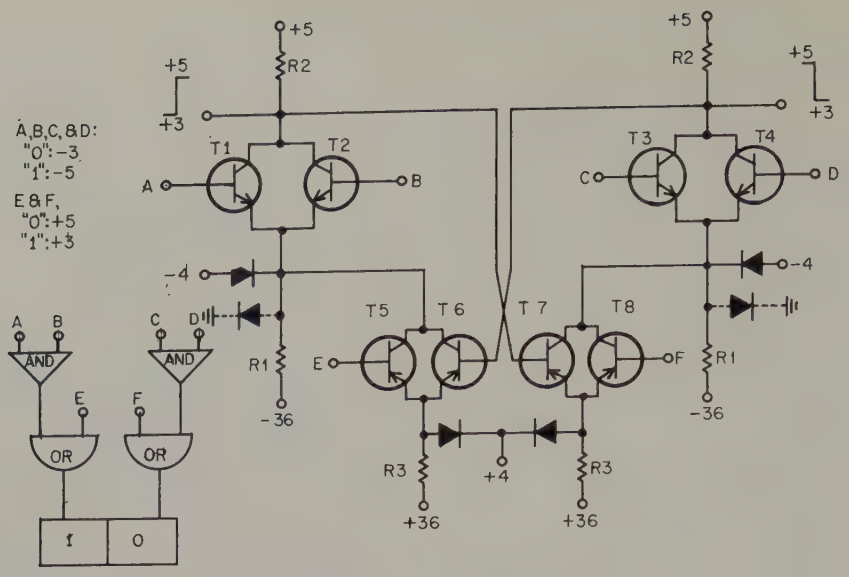

Fig. 9—Flip-flop with internal gates.

inputs to this *OR* gate, additional transistors may be put in parallel with *T5*, so that the conduction of any one of them will cause the flip-flop to change states. The "resetting" of the flip-flop by the application of a signal at point *F* occurs in a similar way, so that *OR* gate action may be accomplished here too. The circuit as shown performs the logic functions as indicated by the logic diagram at the bottom of *Fig. 9*.

If it is desired to have additional outputs from the circuit which are capable of driving *n-p-n* transistors, one or more of the diodes to plus 4 volts may be replaced by a transistor in the manner of *Fig. 8*.

There is one final circuit which we will consider as an example of the application of the inhibit principle. This is the simplified flip-flop circuit of *Fig. 10*. This circuit clearly requires fewer components than any other flip-flops we have considered. Its operation is as follows: The normal level at the *SET* input is minus 3 volts, so that *T1* tends to conduct. The normal level at the *RESET* input is plus 5 volts, so this transistor is *off*. Two stable states are possible, one with *T1* and *T2* conducting, and the other with *T4* conducting. In the former state, the conduction of *T1* causes its collector to become plus 3 volts, which turns *T2 on*. Since *T2* is conducting, *T4* cannot be conducting, so that *T1* is uninhibited, and able to conduct. Now let us assume that the base of *T1* is momentarily made more negative than minus 4 volts, so that *T1* becomes back biased. This will cause its collector to go to plus 5 volts, thus cutting off *T2* causing the conduction of *T4*. This, in turn, inhibits *T1* so that it will remain *off* even after its base returns to minus 3 volts. Now under these conditions suppose that the base of *T3* is pulled momentarily more negative than plus 4 volts, causing *T3* to become conductive and *T4* to turn *off*. When *T4* stops conduction, *T1* is uninhibited and hence conducts. This causes the conduction of *T1* which in turn causes the conduction of *T2*, hence assuring that the flip-flop remains in the new stable state even after the trigger pulse leaves the base of *T3*.

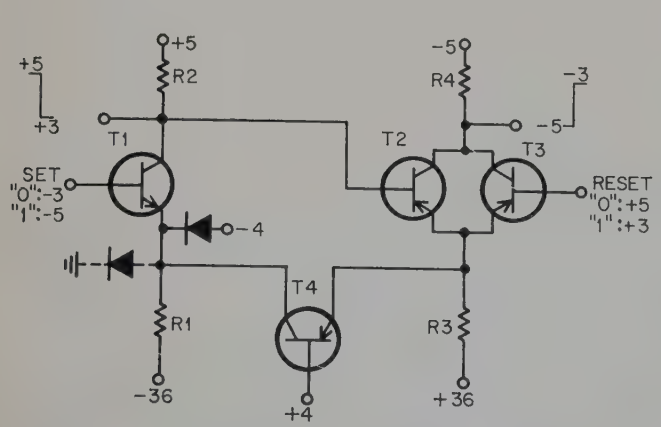

Fig. 10—Simplified flip-flop circuit.

Although the non-symmetry between the *SET* and *RESET* inputs, and between the two outputs, limits the application of this circuit in some cases, its simplicity makes it quite desirable for those applications where the lack of symmetry is not a drawback. Although not indicated in the figure, gating on the *SET* and *RESET* inputs may easily be accomplished by adding transistors in parallel with *T1* and with *T3*. In the former case, the result is an *AND* gate, while in the latter case, an *OR* gate is formed.

Conclusion

Current switching circuits have the feature that they may be operated well out of the saturation region, thus causing higher switching speeds. The inhibit technique retains this, and other features of current switching circuits, while providing the circuit designer with an additional tool. This added flexibility makes possible new circuit configurations which have features not found in the more conventional type of configuration.

The Measurement Of Thermal Resistance*

A Recommendation For Standardization

ROBERT F. GATES† and RICHARD A. JOHNSON†

Several methods of measuring the thermal resistance, Θ, of semiconducting junction devices are compared. In particular, a discussion of the reverse current at constant voltage, forward voltage drop at constant current, and short-circuit input impedance (h_{ib}) as external parameters from which the temperature of the junction may be inferred is included. All of these give consistent results with either the constant reference temperature method or constant junction temperature method. The range of linearity of Θ and the effect of various methods of dissipating power at the junction are considered. The specifications of the complete thermal circuit (i.e. mechancial mounting, etc.) is shown to be necessary for consistant results and essential for the comparison of devices of different shapes and dimensions. As a result of measurements on over 200 transistors of over 30 types, the use of forward voltage drop in conjunction with the constant reference temperature method is recommended as the most reliable and convenient method for both germanium and silicon devices.

AT THE REQUEST of the relevant industrial standardization committee (JETEC-14.0), the Semiconductor Devices Measurements Laboratory at Syracuse University undertook a study of the measurement of thermal resistance. This article is based on a report to the sponsors of the laboratory, the Electronic Industries Association. As yet the recommendations resulting from the experimental and theoretical study have not been incorporated by the appropriate JEDEC committee. Nevertheless, we feel that the contents should be helpful to those interested in standardization of the thermal specifications of semiconductor devices.

The conclusions of our study are based on the measurement of thermal resistance of over 200 transistors of over 30 different types. Some caution should be exercised in using the method recommended. In particular, verification of the results for new types of transistors is essential. In general the results apply to all devices in which power is dissipated at a junction but are not directly applicable to devices such as the field effects transistor.

Thermal resistance has been defined by the JTC 14.6 committee as "—the effective temperature rise per unit power dissipation of a designated junction above the temperature of a stated external reference point under conditions of steady state operation."** For the present we will assume that the definition adequately defines a unique parameter of the device. This is discussed in some detail below.

†Syracuse University, Department of Electrical Engineering.

*This work was supported by Electronic Industries Associatic

** Minutes of Meeting No. 36, Dec. 13, 1956 of JETEC 14.0 and the amendment of Meeting No. 37, Feb. 7. 1957.

The power handling capacity of semiconductor devices is largely dependent upon the maximum temperature which the material or junction can withstand. The maximum voltage and maximum current are also limiting factors, but in many cases the maximum temperature rating will be exceeded first. The maximum junction temperature is determined by the temperature at which the reverse saturation current becomes large enough to cause thermal runaway or the temperature at which the density of thermally excited carriers becomes great enough to prevent transistor action. Unless the heat generated at the junction due to losses can be efficiently conducted away from the junction, the junction temperature will soon exceed the maximum. Thus, there exists a relationship between the maximum power and maximum temperature for a given transistor. If we assume a linear relationship we can write

$$T_{j\,max} = T_r + \theta P_{max} \qquad (1)$$

where T_r is the temperature of the reference and θ is the thermal resistance from the junction to this reference. The above equation applies for all values of T_j and P less than the maximum values and therefore can be written in more general form as

$$T_j = T_r + \theta P \qquad (2)$$

Temperature Sensitive Parameters

Inspection of Equation 2 indicates that if we are to measure the thermal resistance, the junction temperature must somehow be measured. Unfortunately, however, in actual devices the junction temperature cannot be measured directly, and therefore some means of inferring the junction temperature from external measurements must be relied upon.

There are many parameters of the transistors which vary with temperature and much has been done to determine how they vary.[1], [2], [3] The parameter most frequently used for thermal resistance measurements is I_{CBO} or the saturation current of a reversed biased junction.[4] The use of I_{CBO} as a temperature sensitive parameter (TSP) is adequate, but not completely reliable for germanium devices, and is unreliable for silicon devices.

The voltage drop across a forward biased junction is a TSP which is equally reliable for both silicon and germanium. The variation of this drop can be determined analytically from the diode equation

$$I = I_s(T)\left(\epsilon^{\frac{qV}{nkT}} - 1\right) \tag{3}$$

Where $I_s(T)$, the reverse saturation current, varies approximately as*

$$T^{\frac{5}{2}}\ \epsilon^{\frac{-qV_g}{nkT}} \tag{4}$$

* The 5/2 power comes about by considering the temperature dependence of the mobile carriers' density, diffusion rate and lifetime. In any particular device the 5/2 may vary slightly because these factors are also dependent upon the impurity concentration. The n in the exponential term is accounted for by the generation-recombination centers existing in the space charge region of the junction. It has been shown[5] that this effect increased as the energy gap and conductivity increase. Thus, the numbers $n \approx 1$ and $n \approx 2$ for germanium and silicon respectively are approximate and vary depending upon the impurity concentration. Although these factors will influence the magnitude of the numbers involved in the calculations they will not change the general form of the curves.

For convenience in interpretation we may write

$$I_s(T) = I_{so}\left(\frac{T}{298}\right)^{5/2}\ \epsilon^{\frac{qV_g}{nk}\left(\frac{1}{298} - \frac{1}{T}\right)} \tag{5}$$

where I_{so} is the reverse saturation current at 25°C (298°K). Substituting Equation 5 into Equation 3 and solving for the forward voltage drop V, we get

$$V = V_g\left(1 - \frac{T}{298}\right) + \frac{nkT}{g}\ln\left(\frac{I + I_s(T)}{I_{so}}\right) - \frac{5}{2}\frac{nkT}{q}\ln\frac{T}{298} \tag{6}$$

This equation is plotted in *Fig. 1* for germanium for various values of forward current to reverse saturation current ratios. A similar curve may be plotted for silicon. Note that the slope of these curves is essentially independent of temperature for I/I_{so} greater than 1000. Experimental results show that a current ratio of 1000 gives an initial voltage at 30°C of approximately 0.25 volts, indicating that there is a contribution to the voltage due to the resistance of the semiconductor material, contacts and leads. *Fig. 2* shows the results of tests on three different types of germanium transistors in which the forward current was adjusted to make the voltage drop exactly 0.25 volts at 30°C. Note that the slope of the experimental curves agrees well with theory, and only the slope is necessary in the measurement of thermal resistance.

An experimental test network for measuring thermal resistance using the voltage drop across the forward biased collector junction is shown in *Fig. 3*. Contacts S_{1a} and S_{1b} are contacts on the same mercury relay and are used to open the normal emitter and

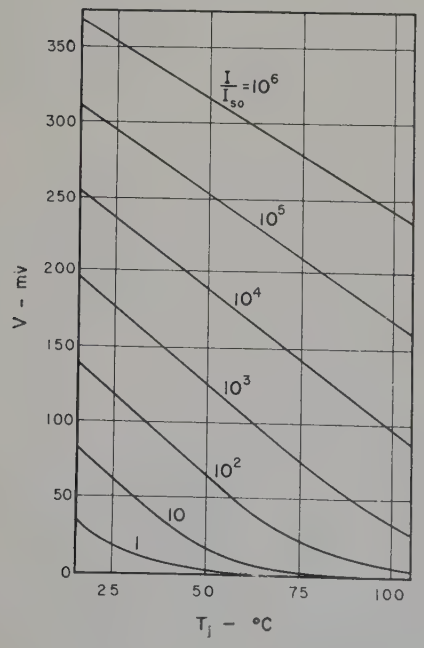

Fig. 1—Forward voltage drop of germanium junction.

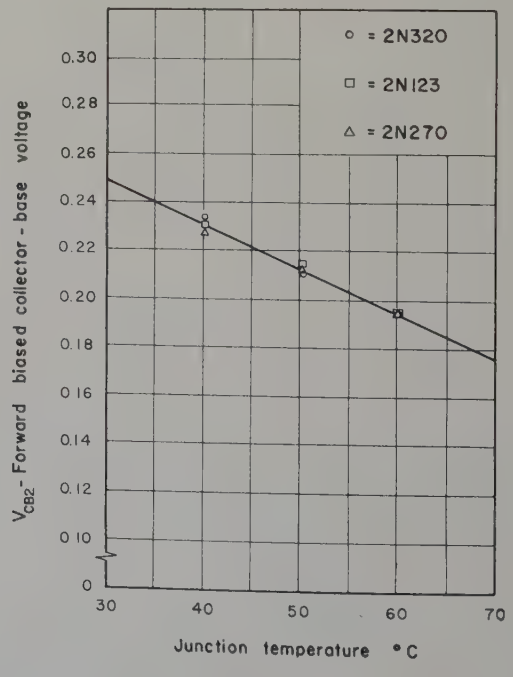

Fig. 2—Forward voltage drop of germanium junction as a function of junction temperature.

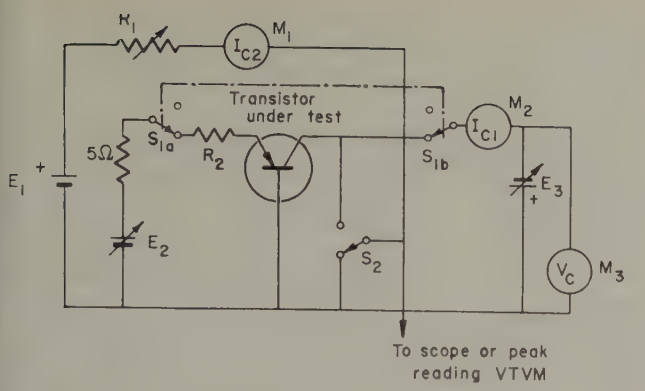

Fig. 3—Network using V_{CB} forward as the TSP.

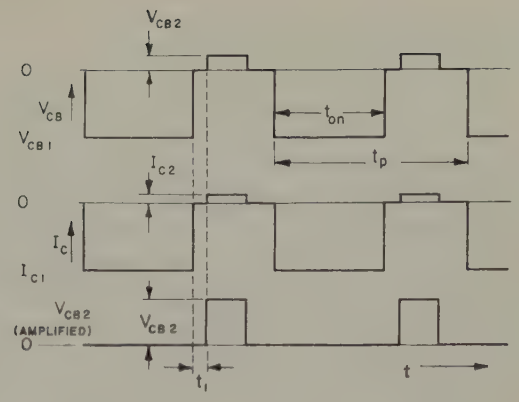

Fig. 4—Time relationships in the V_{CB} test network.

collector circuits, while S_2 is a set of single pole double throw contacts on a second mercury relay which applies the forward bias to the collector junction during the *off* period, places the measuring instrument across the junction and also establishes the ground reference for the measuring instrument during the *on* period. The two relays are controlled to give the waveforms shown in *Fig. 4*. In a further refinement of the network the relays could be replaced by switching transistors. Time t_1 is adjusted to be as small as possible while avoiding the transient effects of turning off the transistor. The potentiometer R_1 is used to set the initial value of V_{CB2} at 30°C. Making E_1 a high voltage insures that I_{C2} is a constant current once R_1 has been adjusted. Supply E_2 and potentiometer R_2 are used to adjust the normal collector current I_{C1} while E_3 is used to adjust the normal collector voltage. The power dissipated in the transistor may be determined from the readings of M_2 and M_3.

An experimental investigation of the common base input impedance (h_{ib}) indicates that it is primarily a function of junction temperature and emitter current and is essentially independent of V_C except insofar as V_C affects the power, which in turn, affects the junction temperature. *Fig. 5* shows the results of measurements on two power transistors. Here T_j has been determined from independent measurements of θ and Equation 2. Note that h_{ib} is independent of V_C when the change in collector power is taken into account. Accordingly, h_{ib} at constant I_E can be used as a TSP.

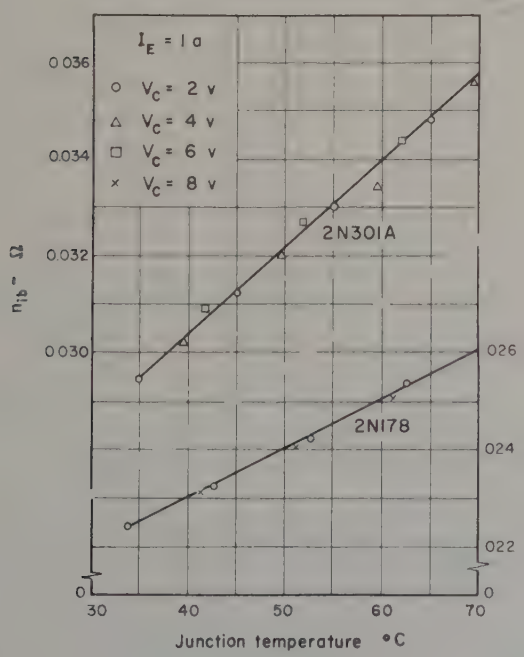

Fig. 5—Variation of h_{ib} as a function of junction temperature.

Measurement Technique

Thermal resistance may be measured by two different methods. In the constant junction temperature method a TSP is observed with a small amount of power, P_1, being dissipated while the reference temperature is maintained at a high value.[4], [6] The external reference temperature is lowered by a known amount and additional power is dissipated in the device until the TSP measures the same as before. This indicates that the temperature of the junction is the same as before. The thermal resistance may then be determined from

$$\theta = \frac{T_{r1} - T_{r2}}{P_2 - P_1} \qquad (7)$$

T_{r1} is the initial reference temperature and T_{r2} is the final reference temperature. The first step of this procedure is essentially a calibration of the TSP. For convenience P_1 is usually set equal to zero.

The second method, which may be called the constant reference temperature method, requires the calibration of the TSP *vs* temperature with no power being dissipated in the device. If the TSP is a linear function of temperature it is only necessary to know the slope of calibration curve. The external reference temperature is held constant and power is dissipated in the unit and the TSP is measured. From this measurement the junction temperature is inferred by using

the calibration. The thermal resistance may then be calculated (using Equation 2) from

$$\theta = \frac{T_{j2} - T_{j1}}{P_2 - P_1} \qquad (8)$$

Again P_1 is usually set equal to zero for convenience.

The definition given in the introduction implies that a point to point measurement determines a unique thermal resistance. This definition is not adequate because, in general, the temperature difference between two points on a device will depend on the mechanical (i.e. thermal) mounting of the device. As an extreme example, the temperature difference between the top of the case of a power transistor and the junction depends on the mounting of the transistor. A similar statement may be made for any choice of external reference point since there is a multiplicity of distributed heat paths rather than a single "lumped constant" path between points. Accordingly, the thermal resistance between the junction and another point is not unique but depends on the thermal mounting. The problem is further complicated by the fact that it is essential that similar devices with different shapes must be compared. In view of the above, we have implicitly modified the definition of thermal resistance to read

> "Thermal resistance shall be defined as the effective temperature rise per unit power dissipation of a designated junction above the temperature of a stated external reference point *on a specified mounting* under conditions of steady state operation."

The situation with regard to the precise definition of thermal resistance is quite analogous to that encountered in the measurement of inter-electrode capacitance in electron tubes. For meaningful results it has been found necessary to specify a standard socket for standard inter-electrode capacitance measurements. For both measurements the distributed nature of the measured quantity is important.

The need for specifying the thermal mounting is most apparent for conduction cooled power devices. While experimental results for a given mounting are consistent regardless of the method and TSP used, slight changes in the mounting cause significant differences in the measured values of thermal resistance. The experimental thermal mounting used for measuring the thermal resistance of conduction cooled devices is shown in *Fig. 6*. The external reference point is any point in the cooling water which is essentially an infinite heat sink. The dimensions shown were chosen so that all available power devices could be mounted in essentially the same way for a direct and fair comparison. Even though the thermal resistance measured with this mounting may be slightly higher than that obtained using a point on the case as a reference point, we believe the measurement is more significant for the following reasons:

1) the mounting approximates the design of heat sinks used in practice,

2) the measured values are more realistic for practical applications, and

3) a useful, direct comparison between devices of different size and shape is possible.

For low and medium power devices which depend on convection and radiation for removal of heat, the thermal resistance from point to point on the case is small as compared to the thermal resistance from any point to the surroundings. Accordingly, the case of the transistor is essentially a thermal "equipotential" (isotherm) with all points at the same temperature. For such devices any point on the case of the device serves as a convenient external reference point. The measurement of the thermal resistance from junction to case is easily accomplished by making thermal contact between the whole case and a heat sink. The simplest mounting is to immerse the device in a liquid of known temperature. In addition to the thermal resistance from junction to case the external thermal resistance from case to surroundings should be given in a complete specification. Aronson gives several useful formulae for calculating the external thermal resistance.[7]

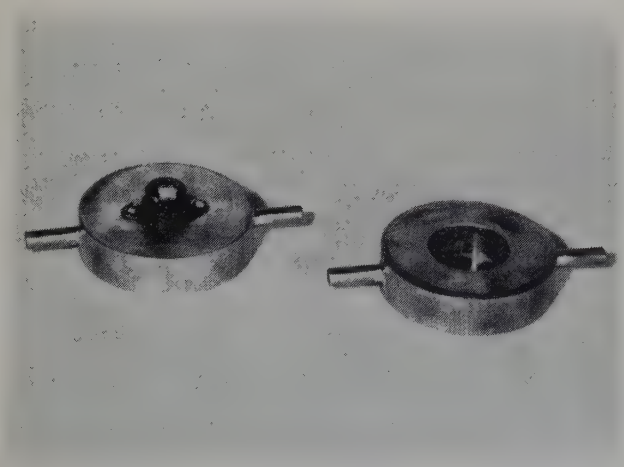

Fig. 6—Thermal mounting for conduction cooled devices.

Sources Of Error

If the thermal resistance of a device is to be characterized by a single measurement it is of interest to determine the range of temperatures and powers for which the thermal resistance is essentially constant. In *Fig. 7* the junction temperature of a typical device is plotted against the power dissipated at the junction for various values of the reference temperature. The data are consistent with Equation 2 within the experimental error. Accordingly the methods described previously will yield consistent results for any values of T_j, T_r and P within the indicated range.

Another possible source of error lies in the method by which power is dissipated at the collector junction. Experimentally we find that within the rated maximum values any combination of current and voltage

which results in the same power produce the same indication of junction temperature. This is further justification for the implicit assumption that the power is in fact dissipated at the junction.

Since most of the methods of measurement considered require that the power be interrupted while the measurement of junction temperature is made, the duty cycle of the timing sequence may be important. Here, duty cycle is defined as

$$d = \frac{t_{on}}{t_p} \tag{9}$$

where t_{on} is the time interval during which power is applied and t_p is the period of the cycle. The effect of the duty cycle can be determined for two limiting cases without detailed knowledge of the thermal transient response of the system. If the *on* portion of the cycle is long enough for the thermal circuit to reach the steady state condition, and if the measurement is made immediately after the power is interrupted, the *peak* values of collector current and voltage should be used in calculating the power. Thus

$$P = V_{peak}\, I_{peak} = V_{CB1}\, I_{C1} \quad \text{for } t_{on} \gg \text{thermal response time constants} \tag{10}$$

On the other hand, if the period is much shorter than the relevant thermal response times, the average value of power will determine the junction temperature. Accordingly,

$$P = \frac{1}{t_p} \int_o^{t_{on}} E_{peak}\, I_{peak}\, dt$$

$$= V_{CB1}\, I_{C1}\, d \quad \text{for } t \ll \text{thermal response time constants} \tag{11}$$

If neither of the above conditions is met the relation between the power applied and junction temperature depends on detailed knowledge of the thermal response. This approach is not feasible because of the complexity of the thermal circuit. Note, however, that if the duty cycle is large, and if the measurment is made immediately after power is interrupted, the maximum difference between the two extreme cases above is given by Max error = 100 (1-d)%. Accordingly, if the *on* time is 9/10 of the period the maximum error is 10%. In any case the error will not affect the comparison of similar transistors.

Conclusions

Perhaps the most important conclusion to be drawn from our experimental work is that a standard thermal mounting as well as the reference point must be specified if transistors of different physical dimensions and shapes are to be compared. Included in the specifications should be complete mechanical details such as the materials used in the construction, finish of the part which contacts the transistor, and the torque applied to fasteners which hold the transistor to the

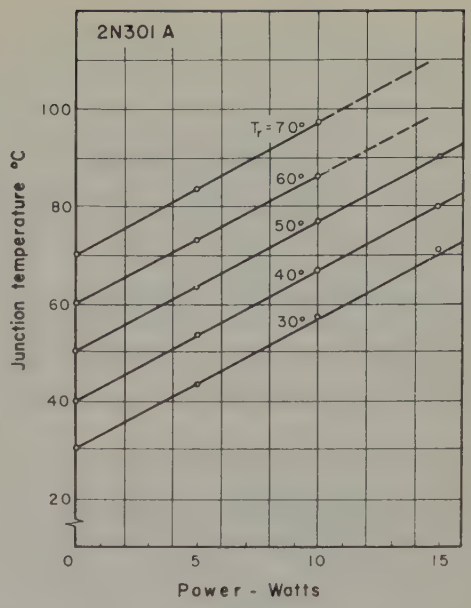

Fig. 7—Junction temperature as a function of power dissipated for different values of reference temperature.

mounting. We suggest, for example, a thermal mounting such as that shown in *Fig. 6* for all conduction cooled power transistors, and also recommend that the external reference point be any point in the circulating water. *Fig. 8* illustrates the thermal mounting with two different types of power transistors and the specifications necessary for reproducibility.

The following points summarize our conclusions

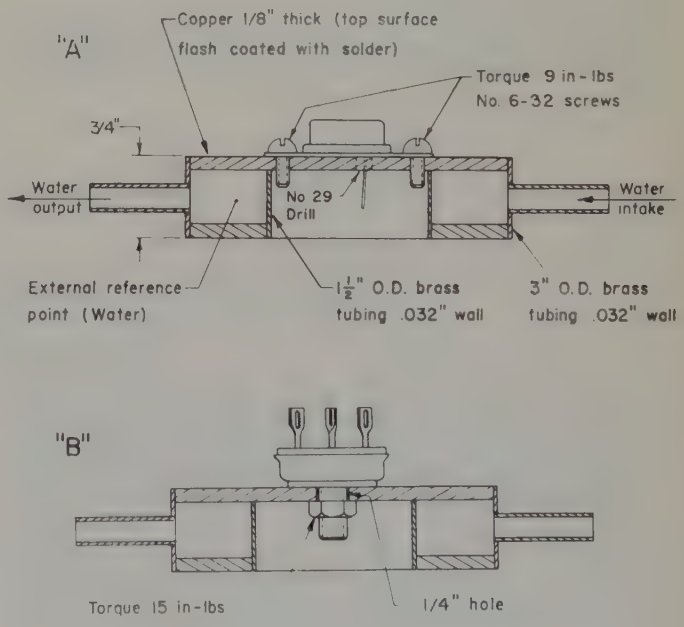

Fig. 8—A recommended standard thermal mounting for power transistors. (a) Cross-section view of thermal mounting adapted to hold Diamond Auto-Radio transistors such as 2N301, 2N178, 2N456, 2N387, etc. (b) Cross-section of thermal mounting adapted to hold stud mounted transistors such as H-4A, H-7, H-10, 2N156, etc.

concerning the relative advantages of the various methods and test networks discussed above.

1. All three of the temperature sensitive parameters, in conjunction with an appropriate test network, may be used with either the constant reference temperature method or the constant junction temperature method. The results obtained are consistent within the experimental error.

2. When I_{CBO} or h_{ib} is used as a TSP, the constant junction temperature method is preferable because it requires no calibration. If the constant reference temperature method is used, each unit must be precalibrated.

3. From our measurements, h_{ib} is not a function of V_C except insofar as T_j is a function of V_C. This result is consistent with device theory. If we assume that h_{ib} depends only on the collector power, the test network is simple in that no switches or relays are required. Note, however, that calibration of each unit is stll required if the constant reference temperature method is used. Also, since I_E must be maintained constant, the range of collector dissipation is restricted.

4. When the forward voltage drop is used as a TSP, calibration is essential in principle. However, for all germanium units tested to date the temperature dependence has been linear with a slope of 1.8 $mv/°C$ when the constant current forward bias is adjusted for a forward voltage drop of 0.25 volts at 30°C. If one accepts this constant, no calibration is necessary and the constant reference temperature method becomes a simple and rapid method. For transistors of radically different design the constancy of the slope should be checked by calibrating several units. The temperature dependence of the forward voltage drop across a silicon junction appears to be linear also with a slope of 2.0 $mv/°C$, when the bias current is adjusted for 0.5 volts at 30°C. However, since we have not tested many different types, additional measurements are necessary to establish whether this value applies to all silicon units.

In summary, use of the forward voltage drop as an indication of temperature in conjunction with the constant reference temperature method appears to be the most desirable way of measuring thermal resistance for both germanium and silicon devices.

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Effect of Emitter Bypass Capacitance On Frequency Response Of a Grounded-Emitter Transistor Amplifier Stage

THOMAS R. HOFFMAN*

An expression for the current gain as a function of frequency is derived for a single-stage grounded emitter transistor amplifier. Low frequency behavior is seen to depend primarily on the size of the emitter bypass capacitor. A plot of current gain magnitude versus frequency reveals two low frequency "breaks"—the lowest a 6 db/octave rise and the other a 6 db/octave drop that cancels the first at all higher frequencies. Expressions for the break frequencies are derived in terms of the emitter bypass capacitance and the various resistors of the circuit. A numerical example using practical values for all circuit and transistor parameters is worked out to illustrate the use of the general formulae.

THE CIRCUIT of a grounded emitter transistor amplifier is shown in *Fig. 1*. The desired quiescent operating point is attained by appropriate choice of R_1, R_2 and R_E. Capacitor C_E is supposed to bypass R_E so that the emitter will be at ground potential as far as a-c effects are concerned. R_L is the load impedance. The signal current I_S is assumed to come from a constant-current source. Current gain of the circuit is I_L/I_S. This ratio will be investigated as a function of frequency for frequencies low enough so that no parasitic capacity or carrier transit time effects need be considered.

Derivation of a Universal Current Gain Formula

The small signal equivalent circuit for *Fig. 1* is shown in *Fig. 2*. R_b represents the parallel resistance of the biasing resistors R_1 and R_2. The parallel combination of R_E and C_E will be denoted as Z_E.

The Maxwell mesh equations for the circuit of *Fig. 2* are shown below:

$$I_S R_b = I_b\,(R_b+r_b+r_e+Z_E) - I_L\,(r_e+Z_e)$$

$$0 = -I_b\,(r_e+Z_E-r_m) + I_L\,(r_e+Z_E+r_c\,[1-\alpha]+R_L)$$

Solution of these for the current gain ratio yields the following:

$$K_i = \frac{I_L}{I_S} = \frac{R_b\,(r_e+Z_E-r_m)}{(R_b+r_b+r_e+Z_E)\,(r_e+Z_E+r_c\,[1-\alpha]+R_L) - (r_e+Z_E)\,(r_e+Z_E-r_m)}$$

This may be regrouped to read:

$$K_i = \frac{R_b\,(r_e+Z_E-r_m)}{(r_e+Z_E)\,(r_e+R_L+R_b+r_b)+(R_b+r_b)\,(r_c[1-\alpha]+R_L)}$$

A complete general analysis of this equation is difficult because of its complexity. The manipulations can be greatly simplified, and the results much more readily interpreted, however, if it is assumed that for all situations of interest $r_m \gg (r_e + Z_e)$. That this as-

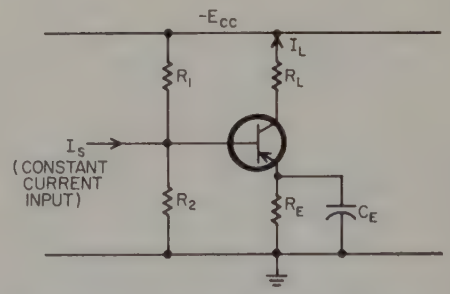

Fig. 1—Grounded emitter amplifier.

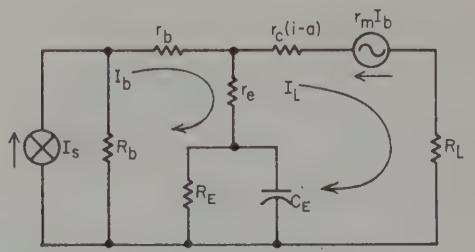

Fig. 2—Small signal equivalent circuit.

*Professor of Electrical Engineering, Union College, Schenectady, New York.

sumption is warranted from a practical viewpoint is easily established. r_e is inherently very small. Z_e is the parallel impedance of R_E and C_E. The permissible size of R_E is limited by the fact that the *d-c* emitter current must pass thru it. In small-signal transistors the inequality normally represents a factor of from 100 to 1000, even if C_E is neglected entirely!

With the foregoing assumption, the current gain expression may be written as follows:

$$K_i = \frac{-A}{r_e + Z_E + B}$$

where:

$$A = \frac{R_b\, r_m}{r_c + R_L + R_b + r_b}$$

$$B = \frac{(R_b + r_b)\, r_c\,[1-\alpha] + R_L)}{r_c + R_L + r_b + R_b}$$

$$Z_E = \frac{R_E}{1 + j\,\omega\, C_E\, R_E}$$

In terms of radian frequency ω, the ratio becomes:

$$K_i = \frac{-A\,(1 + j\,\omega\, C_E\, R_E)}{(r_e + B)\,(1 + j\omega\, C_E R_E) + R_E}$$

which, upon further rearranging, becomes:

$$K_i = \frac{-A}{r_e + R_E + B}\left[\frac{1 + j\,\omega\, C_E\, R_E}{1 + j\,\omega\, C_E\, R}\right]$$

where:

$$R = \frac{R_E\,(r_e + B)}{R_E + r_e + B}$$

Now define:

$$\omega_E = \frac{1}{C_E\, R_E}$$

$$\omega_R = \frac{1}{C_E\, R}$$

$$K_0 = \frac{-A}{r_e + R_E + B}$$

In terms of these normalizing parameters, the universal gain formula becomes:

$$K = \frac{I_L}{I_S} = K_0\left[\frac{1 + j\,\frac{\omega}{\omega_E}}{1 + j\,\frac{\omega}{\omega_R}}\right]$$

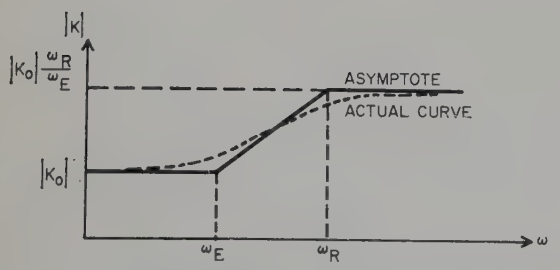

Fig. 3—|K| vs ω.

Note that R must always be less than R_E, hence ω_R is always greater than ω_E. *Fig. 3* shows both the asymptotic plot (or "Bode diagram") and the actual curve for $|K|$ *vs* ω. As ω approaches zero, $|K|$ approaches $|K_0|$. As ω becomes large, $|K|$ levels off at a value of

$$|K_0|\,\frac{\omega_R}{\omega_E}.$$

Approximations That Simplify The Universal Equation

The results of the previous section required only the approximation that $r_m \gg r_e + Z_E$. If, in addition, certain other approximations are made, the shorthand notation of the universal equation can be eliminated and the results expressed directly in terms of the circuit parameters.

First consider the quantities designated as A and B. If it is assumed that the collector resistance r_c is much larger than the sum of R_L, R_b and r_b (almost always true), and also that $r_c\ (1 - \alpha)$ is much larger than R_L (often the case—particularly if the effective load resistance is the input resistance of another transistor stage), expressions A and B reduce to:

$$A \cong \alpha\, R_b$$

$$B \cong (R_b + r_b)\ (1-\alpha)$$

The quantity denoted as R now simplifies to:

$$R = \frac{R_E\,[r_e + (R_b + r_b)\ (1-\alpha)]}{R_E + r_e + (R_b + r_b)\ (1-\alpha)}$$

The ratio of the break frequencies ω_R and ω_E thus becomes:

$$\frac{\omega_R}{\omega_E} = \frac{R_E}{R} = 1 + \frac{R_E}{R_E + r_e + (R_b + r_b)\ (1-\alpha)}$$

To keep this ratio small (which means that the gain change due to inadequate emitter bypassing is kept small), R_E should be small and R_b large. In other words, the base bias source resistance R_b should be much larger than the emitter bias resistor R_E to keep the ratio of ω_R to ω_E near unity.

The general conclusion about C_E is that it should be as large as possible to minimize its effect on frequency response of the stage. It should be mentioned, however, that it is possible to use break frequencies ω_R and ω_E to advantage in certain applications. One such has been suggested for transistor video amplifiers.† It is pointed out that if ω_E is made to coincide with one of the high-frequency breaks of the amplifier circuit, the flat region of the gain *vs* frequency curve will be extended. This is done, of course, at the expense of gain magnitude in the flat range, in accordance with the familiar gain-area theorem.

†"Transistor Amplifier for Radar Video," R. Leslie, *Electronics*, August 1956.

Illustrative Example

To illustrate the use of the relationships derived above, consider the following numerical example. Both circuit and transistor parameters are typical of those encountered in small-signal applications. Note that R_L is taken to be 20K, so that the approximation regarding the size of R_L relative to $r_c\ (1-\alpha)$ is not valid.

Example:

circuit constants (refer to *Fig. 1*):

$$\left.\begin{aligned} R_1 &= 100\text{ K} \\ R_2 &= 25\text{ K} \end{aligned}\right\} \text{ so } R_b = 20\text{ K}$$

$$R_E = 1\text{ K}$$

$$C = 50\text{ mfd}$$

$$R_L = 20\text{ K}$$

transistor parameters:

$$r_b = 200\text{ ohms}$$

$$r_e = 20\text{ ohms}$$

$$\left.\begin{aligned} r_c &= 1\text{ megohm} \\ \alpha &= 0.95 \end{aligned}\right\} \text{ so } r_m = 950\text{ K}$$

The normalizing constants are now evaluated, giving:

$$A = \frac{R_b\, r_m}{r_c + R_L + R_b + r_b} = 18{,}270\text{ ohms}$$

$$B = \frac{(R_b + r_b)\,[r_c\,(1-\alpha) + R_L]}{r_c + R_L + R_b + r_b} = 1360\text{ ohms}$$

$$K_0 = \frac{-A}{r_e + R_E + B} = -7.68$$

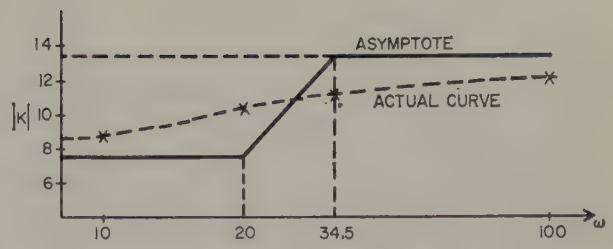

Fig. 4—K_1 vs ω, showing breaks due to C_e.

This is the gain for $\omega = 0$ (i.e.—the *d-c* gain). Further substitutions give:

$$\omega_E = \frac{1}{C_E\, R_E} = 20\text{ rad/sec}$$

$$R = \frac{R_E\,(r_e + B)}{R_E + r_e + B} = 580\text{ ohms}$$

$$\omega_R = \frac{1}{C_E\, R} = 34.5\text{ rad/sec}$$

$$\left|K_0\right| = \frac{\omega_R}{\omega_E} = -13.24$$

This makes the gain for ω large enough so that C_E is no longer a factor (i.e.—the midband gain of the amplifier).

The results of the foregoing example are plotted in *Fig. 4*. Both the asymptotes and the actual gain values are shown.

In summation, it is noted that in this particular numerical example the current gain magnitude rises from 7.68 at *d-c* to 13.24 at frequencies high enough to make the reactance of C_E negligibly small.

New Solutions to the Diffusion Equation

WORDEN WARING*

Diffusion techniques are now widely used for making semiconductor devices. Concentration profiles may be obtained by analog solution of the diffusion equations for conditions making exact analytical solution extremely impractical. Further, the machine computation technique is flexible; various conditions of actual diffusions may be simulated readily and the effects observed. In this article are presented the general technique used, together with some solutions to three particular problems: the effect of later heating (double diffusion) on an initial diffusion, diffusion from a liquid alloy dot in through a regrown region to the bulk semiconductor material, and diffusion through a region with one value of the diffusion coefficient into a region with a different value. The application of the results to device design fabrication, and analysis are indicated.

ONE OF THE MOST recently developed techniques for manufacturing semiconductor devices such as transistors and diodes is by the diffusion of doping materials into the semiconductor crystal lattice. Since the electrical characteristics of the devices are determined by their physical structure, it is important to know such properties as depth of penetration, surface concentration, and concentration profile. In studying diffusion phenomena, experimental results must be supplemented by mathematical analysis.

Some of the interesting things that go on when the doping material is diffused in are simple in general

*Head of Chemistry Section, Fairchild Semiconductor Corp., Palo Alto, Calif. The work reported here was carried on when the author was in the Semiconductor Division of Raytheon Mfg. Co., Newton, Mass.

form, but a quantitative description cannot be obtained by a simple analytical procedure. This is an appropriate situation for the use of an analog computer. The work described below shows how a Reeves Electronic Analog Computer (REAC), Model C400, was used in solving the diffusion equations for different conditions of diffusion. The results obtained apply directly to the structure and therefore to the electrical performance qualities of transistors and diodes. One advantage of the analog computation is that various boundary conditions can be applied and the same general operation used to obtain solutions, whereas problems with different boundary conditions may require rather different approaches in order to obtain any satisfactory analytical solutions.

Besides obtaining solutions to the problems, work with an analog computer can also define regions wherein simpler analytical approximations are satisfactory, so that analog solution is necessary only outside these regions.

The present discussion includes descriptions of the circuitry used, of tests of the accuracy and reproducibility of the machine solutions, and of the results of several kinds of problems which were worked out.

Method of Solution

The equation to be solved for one-dimensional diffusion is:

$$\frac{\delta C}{\delta t} = \frac{\delta}{\delta h}\left(D\,\frac{\delta C}{\delta h}\right) \qquad (1)$$

where C is the concentration of diffusant at the distance h in from the surface at the time t, and D is the diffusion coefficient. If D is independent of h, then

$$\frac{\delta C}{\delta t} = D\,\frac{\delta^2 C}{\delta h^2}. \qquad (2)$$

Unfortunately, an analog computer such as the REAC can integrate with respect to only one variable, so equation (2) cannot be solved in this form. The techniques described by Howe and Haneman[1] and others, were used.

The second partial derivative can be approximated as

$$\left(\frac{\delta^2 C}{\delta h^2}\right)_{h=h_j} = \frac{C_{j+1} - 2C_j + C_{j-1}}{(\Delta h)^2} \qquad (3)$$

at a series of selected points indicated by the j values. These stations are equally spaced across the region considered.

Inserting (3) into (2) gives

$$\frac{\delta C}{\delta t} = \frac{D}{(\Delta h)^2}\,(C_{j+1} - 2C_j + C_{j-1}) \qquad (4)$$

Equation (4) may be solved directly on an analog computer. The wiring used is shown in *Fig. 1*, where S_j represents the j'th summer, Inv_j *the* j'th inverter, I_j the j'th integrator, M_j simply a multiple junction, and A_1 and B_j are potentiometers set at a scaling factor suitable for the desired machine speed. As operated, j runs from 1 to 12. The potentiometer settings include multiplication by $D/(\Delta h)^2$, although this is not shown in the figure.

For a simple diffusion in from one surface, connections are as shown in *Fig. 1*, and $C_{13} = 0$ since there is no input at that end of the chain. If the machine is run for only a short time so that C_{12} acquires only a small value, the error in assuming that $C_{13} = 0$ is negligible. A mathematical approximation that can be fed in at C_{13} has been worked out so that the machine can be run for longer times, but so far it has not been necessary to use this more sophisticated arrangement.

Accuracy and Reproducibility of Results

In order to test the results obtained, the machine running times must be converted to corresponding "problem times." This can be done analytically by use of a potentiometer scale factor, or by experimental fitting of reference runs with known mathematical solutions, or by use of one integrator for an internal measurement of time.

In comparing the converted machine results against known theoretical results, several procedures were used. In one, a simple diffusion was run for several different lengths of machine running time, with duplications, and the values of the C_j's obtained were calculated back to a reduced time and compared with the error function complement, which is the precise theoretical solution to Equation (2) for the boundary condition of constant C_o. In 34 runs of this kind, using the analytical time conversion, only 26 of the 408 resulting values of concentration differed from the theoretical values by more than 1 percentage unit of C/C_o (1 volt). This shows reasonably reliable machine behavior, and indicates the accuracy attainable under usual conditions. Twelve of these 26 poorest values were in one run which erred by 5 or 6 units at the worst (central) stations; such a run would be rejected in the usual work, and a

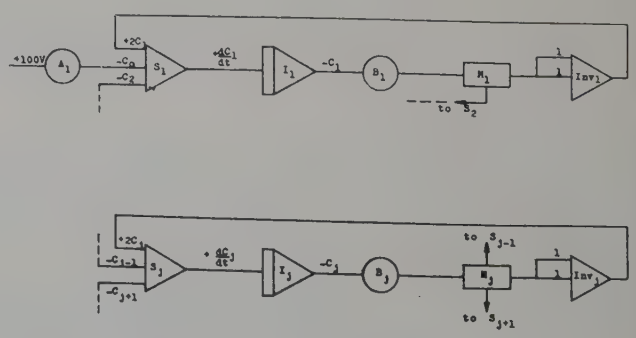

Fig. 1—Basic circuitry for diffusion problems.

rerun would be made. All the other runs clustered closely around the theoretical values. The relative inaccuracies in the values obtained are therefore everywhere less than a very few percent except for the furthest stations (C_{10} to C_{12}) where the absolute values are small. This is quite satisfactory precision for investigating diffusion behavior in semiconductor devices.

A second procedure used in testing the machine behavior is to run a diffusion calculation wherein diffusion proceeds in from both sides: $C_o = C_{13} = +100$ volts. Again, precise theoretical solutions are known for this case and the results can be compared with them. It has been used, however, chiefly as a test of symmetry: the readings on C_6 and C_7, C_5 and C_8, C_4 and C_9, etc., should and do agree within a few hundredths of a volt after various reasonable running times, when the machine is operating properly.

It has been found useful, each time that new work is started on another day, to run a duplicate of some earlier work first. This gives both an additional check on that part of the earlier work, and a check on the machine operation just as the new work is begun.

Results Obtained For Particular Problems

Typical problems which have been worked out conveniently on the analog computer include the following. Others are in progress.

(1) *"Slumping" and Out-Diffusion*

In the fabrication of transistors, an initial diffusion of doping material into the semiconductor bulk is in some processes followed by a second diffusion of a different kind of doping material. During the time of the second diffusion the first material tends to diffuse out of the semiconductor bulk and also to level out its own concentration throughout the bulk ("slump").

Analytical (exact) solution of the diffusion equation starting from an initial concentration distribution described by the error function complement (established by the first diffusion) is not practical. To solve this on the analog computer, the machine is run initially with the usual +100 volts input (C_o), then with zero voltage input ($C_o = 0$).

A one point fit was used to reduce the results to the dimensionless parameter $h/2\sqrt{Dt}$. Smoothing between stations gives the curve shown in *Fig. 2*. They represent the results of diffusing in for a time t' with surface concentration C_o, then diffusing subsequently for a time t'' with zero concentration so slumping and out-diffusion go on. The total time, $t = t' + t''$, is in the abscissa unit; the parameter on the curves is t''/t'. From these results, conclusions such as the following can be drawn. In double diffusion processes, the concentration of the first diffusant should be calculated on the basis of the total time in both diffusions, rather than assuming it is static during the second diffusion. Use of this rule with the *erfc* values will lead to errors of less than 5 percentage units in C/C_o for all values

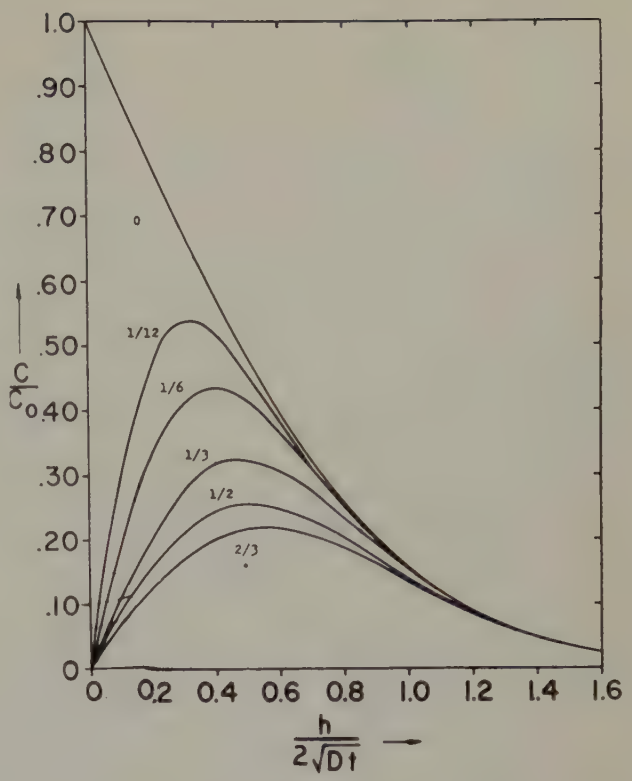

Fig. 2—Slumping and out-diffusion. Parameter on curves is t''/t'.

of $h/2\sqrt{Dt}$ greater than 0.8, and when the second time of diffusion is not more than half as long as the first. For locations nearer the surface than is represented by the 0.8 value for the particular D and t, the appropriate curve in *Fig. 2* should be used.

The effects of such changes in the concentration profile on base width, resistivity, and similar transistor properties are discussed elsewhere by Kaufmann and Freedman.[2] Not only are the concentration values of interest, but in addition the slope of the curve significantly affects properties such as junction capacitance.

It is known to be erroneous to assume that the surface concentration is zero. A better approximation is to assume a surface concentration of some finite value. This value is not known for systems of present interest. To test its effect, several values were assumed for the surface concentration, C_o', for the time of slumping and out-diffusion. In *Fig. 3* are plotted the results when the slumping and out-diffusion.time is just ½ the time of the first diffusion. It is seen that for $h/2\sqrt{Dt}$ greater than about 0.8, the total spread is less than 5 percentage units, regardless of the surface concentration assumed for out-diffusion; but for lower values the particular conditions of out-diffusion may significantly affect device properties.

Instead of a constant surface concentration, a rate limitation at the surface has been used by Smits and Miller[3,4,5] and others.[6,7] In general, this implies a surface concentration varying with time, so that the curves, while falling between the 1.0 and 0 limiting

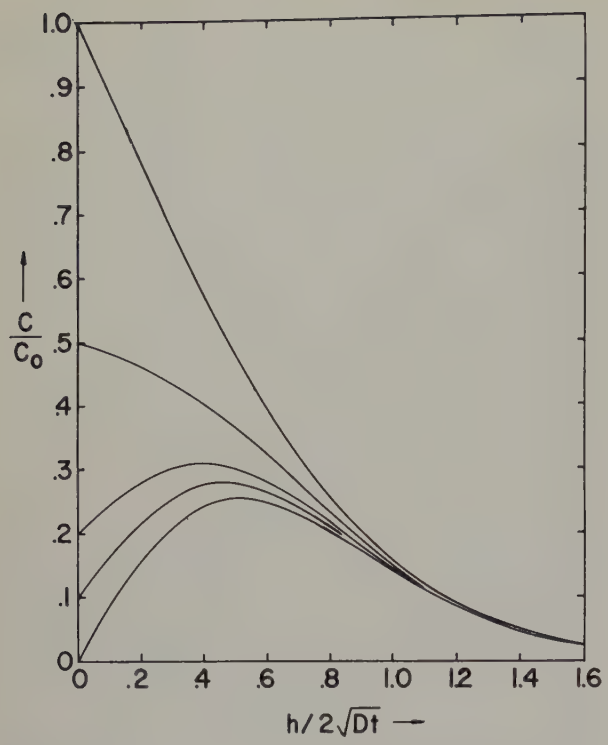

Fig. 3—Effect of C_0 on slumping and out-diffusion.

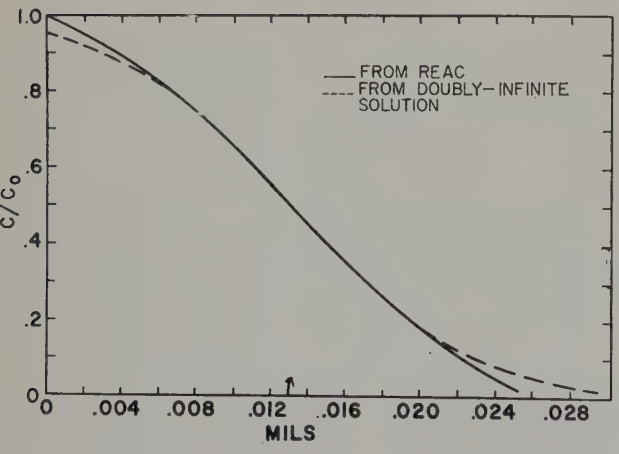

Fig. 4—Diffusion from regrown region; shorter time. Arrow shows boundary distance.

curves in *Fig. 3*, will have a somewhat different shape from the middle curves shown there.

(2) Diffusion from liquid dot through regrown region

A transistor structure (*p-n-p* or *n-p-n*) can be made by firing in a dot alloy containing both *n* and *p* type materials, then cooling slightly to obtain a regrown region, and holding the system at this temperature long enough for the impurities to diffuse into the bulk semiconductor material from the regrown region. The concentrations of dopes are so adjusted that the faster diffusing material will overdope to form the base region, and the slower diffusing material will overdope in the regrown region. This technique was used and described by Benjamin and Longini,[8] and has been developed by Beale,[9] Freedman and co-workers,[10] Schwartz and Slade,[11] and doubtless by others. The diffusion processes are similar to those in the grown-diffused technique.[12,13,14]

To represent this on the REAC, +100 volts was applied through potentiometer A_1 to represent the constant surface concentration, as for the usual in-diffusion. But in addition, −100 volts was applied initially to the first few integrators; the usual zero voltage was applied to all the others. This corresponds to a saturated regrown region from the surface, station zero, in to some selected location, and then zero concentration in the bulk material beyond. Runs were stopped when $C_{12} = 0.10$, 1.00, or 5.00, and machine time was converted analytically to diffusion time.

This problem is quite similar to one which can be solved analytically, wherein there is the same sharp initial distribution, C_o on one side of a boundary and zero on the other, but the regions extend to infinity on each side instead of having a point with fixed C_o as in the present case. The solution to the doubly-infinite problem is given by Jost[15] as

$$C = \frac{C_o}{2} [1 - erf\,(h/2\sqrt{Dt})] \qquad (5)$$

where h is measured in both + and − directions from the boundary, and by definition

$$erf\,(-h/2\sqrt{Dt}) = -erf\,(h/2\sqrt{Dt}). \qquad (6)$$

This distribution can be calculated for the same times, diffusion coefficient, and dimensions (value of Δh) as used in the REAC solution, and the two results compared. Comparison is made by setting the position of the initial boundary surface in the doubly-infinite problem at the halfway mark beyond the last station with initial concentration C_o (that is, at station 3½ or 6½). The resulting graphs, of which only two are presented here, *Figs. 4* and 5, show that for relatively short diffusions or relatively thick regrown regions the doubly-infinite solution represents well the experimental behavior (except at the outer boundary), even after considerable smoothing of the profile has occurred. But for long diffusion times or very thin regrown regions, the difference becomes quite noticeable. *Fig. 4* corresponds to a time of 3.2 minutes if the regrown region is 0.013 mil thick, or other times for other thicknesses; *Fig. 5* corresponds to 18¾ minutes for a 0.014 mil regrown region, or other times for other thicknesses. At the deep penetration end of the curve, the use of $C_{13} = 0$ causes the machine curve to be erroneously low in both *Figs. 4* and 5. Both figures are based on runs wherein C_{12} rose to 5.00, which is much higher than is permitted in most runs.

(3) Diffusion through two layers with different diffusion coefficients

Instead of changing the initial distribution of ma-

terial (concentrations) as in the preceding section, we may start with a surface concentration C_o, maintained constant throughout the problem, and the diffusant going into material with zero concentration of diffusant, but having a different coefficient of diffusion in different layers. This can correspond to diffusion through an oxide layer and then into the semiconductor (two constant but different values of D in different regions) or can correspond to a variation of D with position within the semiconductor (for example, variation of D with the concentration of a prior diffusant, as in double diffusion).

In this case, Equation (1) cannot be differentiated as before. Instead, an approximation is used:

$$\frac{\delta C}{\delta t} = \frac{\delta}{\delta h}\left(D_{j+}\frac{C_{j+1}-C_j}{\Delta h}\right) \tag{7}$$

where D_{j+} is the average value of the diffusion coefficient in the region between j and $(j+1)$. From this the final equation is represented by

$$\frac{\delta C}{\delta t} = \frac{D_{j+}C_{j+1} - (D_{j+}+D_{j-})\,C_j + D_{j-}C_{j-1}}{(\Delta h)^2} \tag{8}$$

where D_{j-} is the value between j and $(j-1)$. If all D's are equal, this reduces to Eq. (4). For those stations where $D_{j+} = D_{j-}$, the wiring in *Fig. 1* is still satisfactory. But where D changes, the modification shown in *Fig. 6* is used.

In one series of machine runs, D was kept constant for j greater than 3, and set at a different but also constant value for j less than 3. The ratio D_{3-}/D_{3+} was set on the two groups of potentiometers as 1/5 for one group of runs and as 5/1 for another, with the results shown in *Figs. 7* and *8*. In both cases, D in the bulk material is taken as 1×10^{-12} cm^2/sec, and Δh as 0.01 mil, so the outer layer is 0.03 mil thick. In *Fig. 7*, D in the outer layer is 0.2×10^{-12}; in *Fig. 8* it is 5×10^{-12}. The diffusion times are then approximately as shown in the figures. In such runs, the concentration profiles in the bulk materials can be compared with profiles obtained from simple in-diffusions, and the effects on device structure noted can be related to resulting device behavior.

Limitations In Use of Analog Computer

There are several limitations on the methods described here for solving diffusion problems. In the first place, the range of concentrations which can be directly obtained is not large. The maximum voltage used is 100 volts, and the smallest amount of this reliably measured is under the best conditions about 0.1 volt (readings can be made only to 0.01 volt), so this gives a range of only three orders of magnitude. In some diffusion problems in device fabrication, five or six orders of magnitude may be of interest. It may be possible to set up the REAC to deal with a greater concentration range; this is a problem for future work.

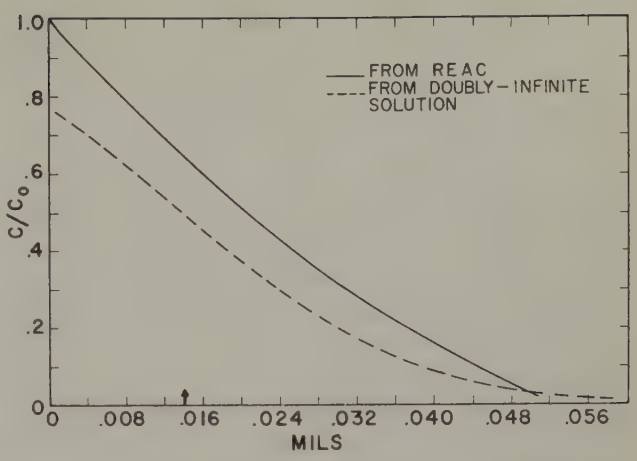

Fig. 5—Diffusion from regrown region; longer time. Arrow shows boundary distance.

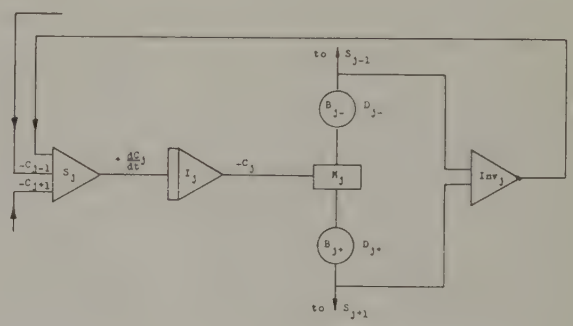

Fig. 6—Circuit for station where D changes.

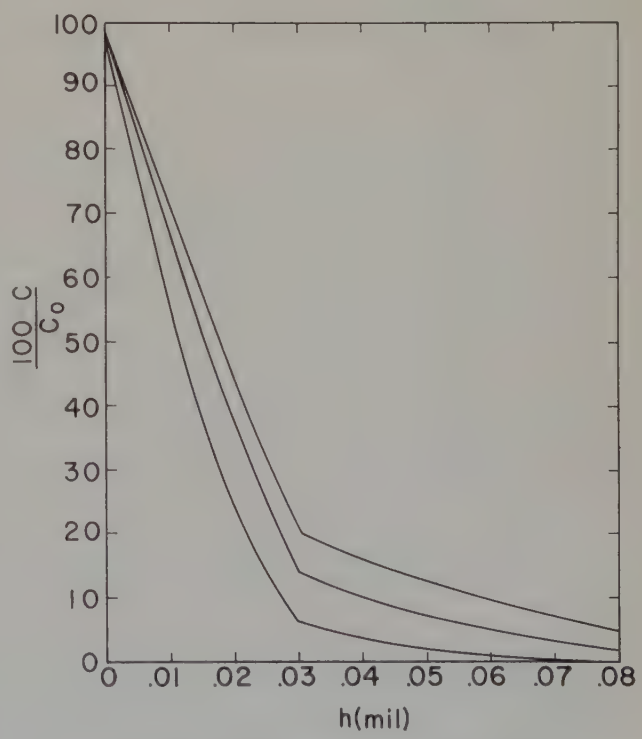

Fig. 7—Slower diffusion in outer layer.

A second limitation is that the derivative $(\delta C/\delta h)_t$ cannot be obtained directly. However, the difference ΔC (corresponding to a chord approximation $\Delta C/\Delta h$) can be obtained and plotted automatically as a function of t.

A third limitation is that the approximation used is poorer at large values of h (stations further in) as machine time goes on: it is less and less adequate to assume that $C_{13} = 0$. This could be improved by using an approximation to feed in an artificial C_{13} as a function of time, but as indicated above there seems no need to use long machine running times in most problems. The magnification (value of Δh) is adequate and stations seem appropriately spaced for analogy to most real diffusion needs.

Conclusion

An analog computer such as the REAC is quite useful in solving diffusion problems, partly because of its convenience for problems analytically difficult and partly because of its flexibility and the ease of changing conditions from one problem to another. The reliability and reproducibility of its numerical results seem quite adequate for the needs of work on diffusion devices. Tests of reliability and reproducibility must be incorporated into each separate problem as far as possible, because as yet no general quantitative statement can be made about these qualities.

Results so far have given concentration patterns resulting from various conditions of diffusion, and have enabled the effects of these patterns on device behavior to be analyzed. In continuing this work, next attention will be paid to variations of D with time and position, and of C_0 with time. Such results seem of value in analyzing the effects of interactions of III-V materials with each other, and the effects of different heating and cooling procedures on the resulting concentration patterns.

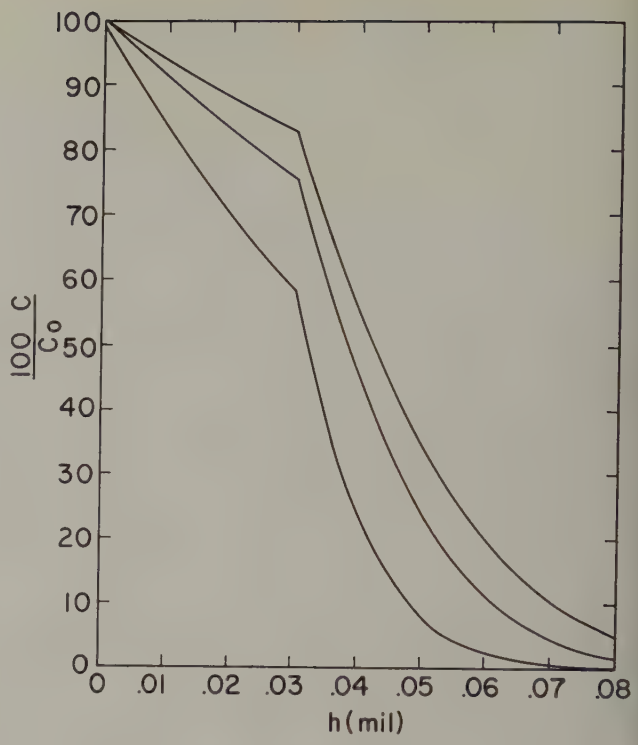

Fig. 8—Faster diffusion in outer layer.

Acknowledgments

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I am indebted to Norman Nicol, supervising the REAC at Raytheon's Research Division, for assistance in setting up the general problem and for our stimulating discussions with regard to this and other analog computations.

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APPLICATIONS ENGINEERING DIGESTS

APPLICATIONS ENGINEERING DIGEST No. 7

Silicon Solar Cells; Ferranti Ltd., Gem Mill, Chadderton, Oldam, Lancs., England.

Silicon Solar Photovoltaic Cells will convert radiant energy from the sun or from incandescent lamps into electrical energy. They have a response time of a few microseconds and operate without deterioration under conditions of high temperature and humidity. A photovoltaic cell is an electrical generator capable of driving current round an external circuit, the *p* region connection becoming positive with respect to the *n* region connection.

This can be approximately represented by an infinite impedance generator, *Fig. 7.1*, of constant photo current *i* in parallel with a silicon diode, where R_D is the cord resistance of the diode. The photo current which has been caused to flow across the junction by the radiation is approximately proportional to the rate at which light quanta impinge on the cell and this current therefore increases with the intensity of the illumination. When the cell has no load connected to it the external current must be zero; therefore the photo current must be balanced by equal forward diode current $i_D = i$. The open circuit voltage V_{DO} is a logarithmic function of the photo current **i** and its upper limit is about 0.6 volts. If the cell is completely short circuited the maximum possible current i_L that can flow is the photocurrent *i*. Under definite load conditions the diode voltage V_D becomes less than the open circuit voltage V_{DO} and the load current i_L less than the short circuit current *i*.

Figure 7.2 shows circuits for deriving an electrical output at or above a predetermined level of light intensity.

In the circuit shown in *Fig. 7.2* the value of the resistor *R* is dependent on the level of light intensity to be permitted before the passage of appreciable transistor collector current. *R* provides a positive bias such that at low levels of light intensity the base current i_B, which now equals I_{co}, flows into the base of the transistor causing cut off. Under these conditions the cell will be biased in the reverse direction, the value of this reverse voltage being limited by the germanium diode. When maximum light falls on the cell causing it to conduct most of the 150 μA or so of current drawn will flow from the base of the transistor and cause it to bottom. The collector voltage of the transistor will therefore vary from about 6 volts negative to almost zero, the balance of the 150 μA taken by the cell flowing from the positive line.

In the second circuit, *Fig. 7.3*, the resistor *R* is connected to the negative line and its value is chosen so that at low levels of light intensity a current of about 125 μA is drawn from the transistor base causing the transistor to bottom; under these conditions the cell will be biased in the reverse direction. When maximum light falls on the cell, causing it to conduct, a path is provided for both the current flowing through *R* and the small base current i_B (which is equal to I_{co}) and this base current causes the transistor to cut off. The value chosen for *R* will determine the level of light intensity to be permitted before the transitor ceases to bottom and in this case the collector voltage will vary from almost zero to about 6 volts negative.

Ed. Note—The OC44 is a *p-n-p* germanium transistor fabricated by Amperex Electronic Corp., Hicksville, N.Y.

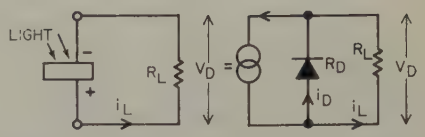

Fig. 7.1—Actual and equivalent circuits for a photovoltaic cell in a simple configuration.

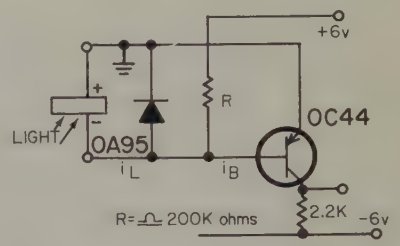

Fig. 7.2—Circuit for deriving an electrical output at or above a predetermined level of light intensity.

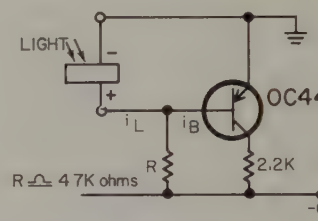

Fig. 7.3—Another circuit for accomplishing the same result as that of Fig. 7.3

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APPLICATIONS ENGINEERING DIGEST No. 8

High Frequency Pulse Generator; Lansdale Tube Co., Lansdale, Pa. (C. I. Swanson)

This report describes a high-frequency pulse generator which was developed for the purpose of testing high speed counting circuits. It is capable of producing pulses with a repetition rate of between 5.5 and 20 *mc.* with a controllable duty cycle. The circuit is shown in *Fig. 8.1.*

Transistor *T1* is used in a Hartley oscillator circuit which tunes the range of 5.5 to 20 *mc.* The output is sufficiently invariant in amplitude to give a reliable output from the clipper. This is accomplished by ganging the feedback and tuning condensers so that the feedback capacitor will approximately compensate for the phase shift in the transistor at any given frequency.

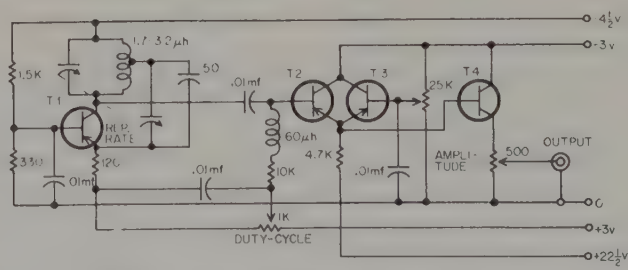

Fig. 8.1—20 megacycle pulse generator.

The *or* circuit clipper selects a portion of the sine wave as determined by the desired duty cycle, and delivers a negative pulse to the emitter load. The duty cycle is determined by the base bias of *T2*. The bias of *T3* serves to clamp the pulse at any desired *d-c* level. This enables one to direct couple the output emitter follower to the *or* circuit load. The output emitter follower is used to provide a reasonable power via a low impedance output.

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APPLICATIONS ENGINEERING DIGEST No. 9

Broadcast Band Amplifier Circuits Using Drift Transistor; Radio Corporation of America, Somerville, N.J.

This digest discusses considerations involved in the design of *rf* amplifier stages using the RCA-2N544 transistor. The 2N544 is a drift transistor of the germanium *p-n-p* alloy type designed specifically for use as an *rf* amplifier at standard broadcast frequencies. Circuits and performance data for the 2N544 in a tuned *rf* amplifier stage with and without neutralization and in an unneutralized "broadband" *rf* amplifier stage are presented. The original application note gives detailed graphical data on the characteristics of the 2N544 which determine its performance in common-emitter *rf* amplifier circuits.

Neutralized tuned *rf* stages, in comparison with unneutralized stages, provide higher power gains and signal-to-noise ratios, and in superheterodyne receivers, more satisfactory rejection of image and other spurious responses. In "broadband"-type circuits neutralization also provides better discrimination against adjacent-channel interference. Cost considerations, however, frequently dictate the use of unneutralized tuned or untuned (broadband) *rf* amplifier stages, especially in portable receivers of the "personal" type. In addition to low cost, the principal advantage of broadband amplifiers is their small space requirements. A broadband amplifier can be made to have the desired bandwidth—for example over the broadcast band—either by the proper choice of shunt resistance or by incorporation of equivalent losses in the output transformer. Substantially uniform response over the entire passband can be obtained if the amplifier is peaked at the high frequency end of the band to offset the reduction of gain resulting from the decreased input impedance of the following stages at the higher frequencies. In such cases the required peaking capacitance can be supplied entirely by the output capacitance of the *rf* amplifier stage and the input capacitance of the following stage.

Figue 9.1 is the circuit and Table 1 the performance data of a tuned *rf* amplifier stage using the 2N544. *Fig. 9.2* is the circuit and Table 2 the performance data of an unneutralized broadband *rf* amplifier stage.

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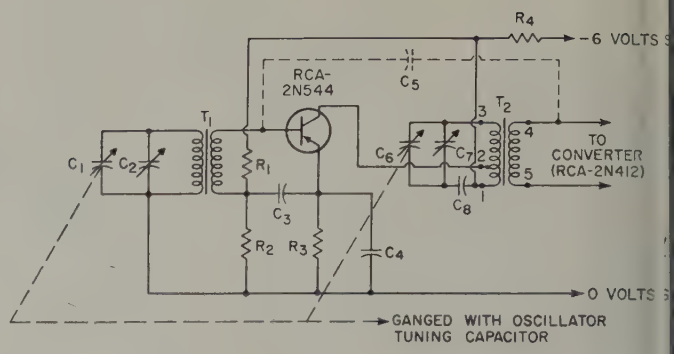

Fig. 9.1 — Circuit of a tuned *rf* amplifier stage with and without neutralization.

C_1, C_6—Tuning capacitor, 22 to 185 mmf, air variable
C_2, C_7—Trimmer capacitor, 2 to 20 mmf, mica variable
C_3, C_4, C_8—0.05 mf, 50 volts, ceramic
C_5—Neutralizing capacitor, 7 mmf. 500 volts, mica
R_1—39000 ohms, 0.5 watt
R_2—3900 ohms, 0.5 watt
R_3, R_4—470 ohms, 0.5 watt
T_1—Antenna Transformer; wound on ¾-inch by ⅛-inch ferrite core, 4 inches long; primary—86 turns No. 3/41 Litz wire; secondary—4 turns No. 3/41 Litz wire; Q at 1 Mc; loaded—100; unloaded—370.
T_2—Interstage transformer

Characteristics	Neutralized	Unneutralized
Primary tuned resistance at 1 Mc—ohms	10200	3630
Primary input resistance at 1 Mc—ohms	9340	3590
Turns ratio—Terminals 1 and 3 to terminals 1 and 2	3.87	6.48
Turns ratio—Terminals 1 and 2 to terminals 4 and 5	3.32	2.12
Unloaded Q at 1 Mc (transformer mounted in chassis)	52	52
Loaded Q at 1 Mc (transformer mounted in chassis)	23.8	25.6

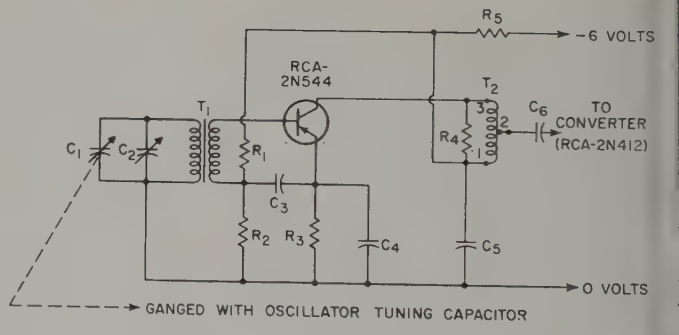

Fig. 9.2 — Circuit of an unneutralized "broadband" *rf* amplifier stage.

C_1—Tuning capacitor, 22 to 185 mmf
C_2—Trimmer capacitor, 2 to 20 mmf, mica
C_3, C_4, C_5, C_6—0.05 mf, 50 volts, ceramic
R_1—39000 ohms, 0.5 watt
R_2—3900 ohms, 0.5 watt
R_3, R_5—470 ohms, 0.5 watt
R_4—2200 ohms, 0.5 watt
T_1—Antenna transformer; wound on ¾-inch by ⅛-inch ferrite core, 4 inches long; primary—110 turns No. 3/41 Litz wire; secondary—6 turns No. 3/41 Litz wire; Q at 1 Mc; loaded—170; unloaded—105.
T_2—Interstage transformer; primary tuned resistance at 1 Mc, 37800 ohms; primary input resistance at 1 Mc (secondary terminated in input resistance of 800 ohms), 4200 ohms; turns ratio (terminals 1 and 3 to terminals 1 and 2), 2.12; Q at 1 Mc (transformer mounted in chassis); unloaded—18; loaded—2.

TABLE 1

FREQUENCY (KC)	POWER GAIN (DB) NEUTRALIZED	UNNEUTRALIZED
600	30	26
1000	32	27
1500	30	26

Table 1—Gain characteristics of the tuned *rf* amplifier shown in Fig. 9.1.

TABLE 2

FREQUENCY (KC)	POWER GAIN (DB)
600	18.5
1000	22.0
1500	20.0

Table 2—Gain characteristics of the "broadband" *rf* amplifier stage shown in Fig. 9.2.

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High-Frequency Gallium Arsenide Point Contact Rectifiers	Bell Syst Tech Jl Jan 1959	Devices operate efficiently as frequency converters at frequencies as high as 60 *kmc*.	W. M. Sharpless
Note on the Motion of Electrons and Holes in Perturbed Lattices.	Can Jl of Phys Jan 1959	A new set of orthogonal localized functions is discussed; an alternative derivation of the effective mass equation is given.	R. R. Haering
Transistor Phase-Locked Oscillators.	Comm and Elec (AIEE) Jan 1959	Two completely transistorized systems have been developed and are described.	K. A. Edwards O. Golubjatnikov D. J. Brady
Theory of Transient Build-Up in Avalanche Transistors.	Comm and Elec (AIEE) Jan 1959	An analysis is given based on an integral equation involving stored minority carrier charge in the base layer.	W. Shockley J. Gibbons
Silicon-Controlled Rectifiers from Oxide-Masked Diffused Structures.	Comm and Elec (AIEE) Jan 1959	A 2-impurity simultaneous-diffusion process for producing structures in silicon suitable for *p-n-p-n* switches	R. W. Aldrich N. Holonyak Jr.
A Stable Direct-Coupled Transistor Servo Preamplifier.	Comm and Elec (AIEE) Jan 1959	Design and performance relationships and *d-c* stability considerations for a 2-stage direct-coupled preamplifier.	A. N. De Sautels
Linear Power Amplifiers Using Dynistors or Trinistors	Comm and Elec (AIEE) Jan 1959	This paper describes two of the many possible magnetic-amplifier transducers, and one of the many possible trinistor output circuits.	F. J. Hierholzer
A Transistorized Compandor	Comm and Elec (AIEE) Jan 1959	Design of the Stromberg-Carlson Type 545 compandor for voice transmission communications circuits.	J. C. Perkins Jr. D. A. Perreault A. F. Perkins
Analysis of Transistor Circuit Losses in RC-Coupled Audio Amplifiers	Electrical Des News Jan 1959	Circuit losses inherent in stabilized RC-coupled amplifiers are discussed and analyzed at audio frequencies.	H. K. Cooper
Introduction to Semiconductor Theory	Electrical Mfg Jan 1959	Summary articles covers theory of solids, qualitative aspects of semiconductors, *p-n* junctions, metal semiconductor contacts, and theory of junction transistors.	R. F. Schwartz
Introduction to Semiconductor Theory	Electrical Mfg Jan 1959	Tutorial review of physical concepts of semiconductors with applications to *p-n* junctions and transistors.	R. F. Schwartz
High-Temperature Capabilities of Germanium Transistors	Electrical Mfg Jan 1959	Temperature stabilization can provide reliable short-term operation of germanium transistors in small-signal amplifiers at 100°C or higher.	J. O. Dick
Silicon Unijunction Transistor, Part 1	Electronic Design Jan 8 1959	Structure and basic characteristics of the unijunction transistor.	S. R. Brown T. P. Sylvan
High Frequency Parameters of Transitors and Valves.	Electronic Eng (Brit) Jan 1959	H-F equivalent circuits are developed; Z,Y, and h parameters for each of these circuits are tabulated.	J. Zawels
Measuring Load Characteristics of Silicon Cells	Electronic Equip Eng Jan 1959	Performance evaluated in test circuit which isolates reverse current from forward current, and removes reverse voltage while forward drop is measured.	R. C. Lynch
Testing Diodes for R-F Noise	Electronic Equip Eng Jan 1959	Noise at *r-f* from semiconductor diodes has been found to involve the reverse recovery transients in the diodes.	J. C. Senn
Hall Effect in Semiconductor Compounds	Elec & Rad Eng (Brit) Jan 1959	Modern applications using indium arsenide and indium antimonide.	M. J. O. Strutt
Measuring Transistor $f_{\alpha co}$	Electronics Jan 2 1959	Accuracy exceeding $\pm 3\%$ up to 30 *mc* and $\pm 5\%$ up to 100 *mc* is obtained with method that can be adapted for production testing.	G. I. Turner
Easing Transistor Loads	Electronics Jan 9 1959	Simple design rules limit current and power dissipation to safe limits when the input stage is overloaded.	W. F. Saunders
Special Circuits for Transistor Receivers	Electronics Jan 9 1959	Four portable transistor receiver circuits are summarized in tabular form. These include autodyne converter, reflex, *avc* diode, and untuned *r-f* stage.	W. E. Sheehan Wm. H. Ryer

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Transistorized Geiger Counter Fits in Probe.	Electronics Jan 16 1959	Ratemeter circuit converts output of Halogen-type counter directly into meter indication corresponding to radiation intensity.	F. S. Goulding
Materials for Infrared Windows, Domes, Lenses	Electronics Jan 16 1959	Table lists properties of representative infrared transmitting materials for military systems, industrial and laboratory equipment.	H. F. Hoesterey
Transitorized 16mm T.V. Remote Film Camera	Electronics Jan 16 1959	Using a 12V *d-c* to 110V *a-c* power supply, unit permits 16-mm sound-on-film camera to be operated in field from 12V nickel-cadmium cells.	E. M. Tink
Differential Amplifier Features D-C Stability	Electronics Jan 16 1959	Incorporates temperature-compensating elements with positive coefficient to obtain superior low drift characteristics.	W. T. Matzen J. R. Biard
Hall-Effect Devices	Electronics Jan 16 1959	Description of gyrator and isolator, circulator, electrical compass, digital-to-analog encoder, product modulator and demodulator, switch, magnetic field meter, transducer, negative-resistance amplifier, magnetic-field-variation meter, and ammeter.	R. K. Jurgen
Function Generator for Sines or Cosines	Electronics Jan 23 1959	Transistorized generator provides an output voltage which is a cosine of the input voltage; also performs as sine function generator.	H. Schmid
New Transistor Works at Gyrogenic Temperatures	Electronics Jan 23 1959	Device is fabricated from a bicrystal formed by two crystal-lattice structures of different grain orientation.	S. Weber
Starved Transistors Raise D-C Input Resistance.	Electronics Jan 30 1959	Bootstrapped-collector circuit provides 500-megohm *d-c* input resistance with 100V input signal; *a-c* resistance is even higher.	B. M. Bramson
Voltage Comparator With High Speed Switches.	Electronics Jan 30 1959	Transistorized unit continuously monitors two *d-c* voltages. When difference between voltages exceeds preset threshold voltage switch delivers up to 2 amps to load.	J.W. Higgingotham H. H. Douglass
Silicon Solar Cells	Electronics Jan 30 1959	Tables indicate characteristics and design comparison data.	J. Kalman
Transistorized F-M Oscillator	Electronics Jan 30 1959	Two-transistor circuit combines a Q multiplier with the Miller effect top roduce FM oscillator and Modulator.	P. W. Wood
The Effect of Recombination at the Non-Rectifying Electrode on the Properties of Germanium Alloy Diodes	Electronics Exp. (Comp Trans) 1/59 Radiotekh i Eleck No 12, Dec 1958	Effects of increasing the recombination rate at the second electrode in diodes with a thin base.	N. A. Penin K. V. Cherkas
Analysis of the Operation of a Wattmeter With a Cavity Resonator Which Makes Use of the Hall Effect in Semiconductors.	Electronics Exp. Part trans 1/59 Izvestia VUZ Rad 7/8/58	The semiconductor pick-up unit is placed at the antinode of the magnetic field in a resonator that is coupled to the basic transmission line by magnetic coupling.	E. T. Shorik
Diffusion Attenuation Part I	IBM Jl R&D Jan 1959	Perturbation methods are applied to calculating the attenuation of signals moving in an electric field.	J. A. Swanson
Diffusion Attenuation Part II	IBM Jl R&D Jan 1959	The amount of diffusion attenuation has been computed as a function of frequency for the case of uniform electric field.	J. A. Swanson K. Y. Sih
The Thermal Equivalent Circuit of a Transistor.	IBM Jl R&D Jan 1959	An exact electrical analogue is given for the thermal system between the collector junction and the constant-temperature environment of a transistor.	P. R. Strickland
Applications of RCA Drift Transistors to FM Receivers	IRE Trans Bdcast & TV Rec Jan 1959	Uses in *r-f*, oscillator, and *i-f* stages. Design, performance, gain, bandwidth, S/N ratio, and frequency stability discussed.	J. W. Englund Harry Thanos
A New AGC Circuit	IRE Trans Bdcast & TV Rec Jan 1959	In a small transistorized receiver it is usually only possible to apply *a-g-c* control voltage to one stage. Circuits are analyzed in detail.	Frank J. Banovic Richard L. Muller
Transient Analysis of Junction Transistors.	IRE Trans Elec Dev Jan 1959	Transient behavior of S.B. and D.J. transistors may be represented by an equivalent network consisting of two diodes and a nonlinear base resistance.	W. F. Gariano
The Germanium Microwave Crystal Rectifier.	IRE Trans Elec Dev Jan 1959	Model to include minority storage carrier effect in microwave mixer crystal diodes is proposed and discussed.	A. C. Macpherson
Effect of Transient Voltages on Transistors	IRE Trans Elec Dev Jan 1959	Analytical expressions are derived to show the different transistor parameters and circuit constants which influence the magnitude of transient energy.	H. C. Lin W. F. Jordan Jr.

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Germanium P-N-P-N Switches	IRE Trans Elec Dev Jan 1959	Germanium *p-n-p-n* diode and triode switches were made to operate primarily on the base field mechanism. Wide and narrow base designs discussed.	I. A. Lesk
On Calculating the Current Gain of Junction Transistor With Arbitrary Doping Distributions.	IRE Trans Elec Dev Jan 1959	Extension of previous treatments provides means of calculating current gain for any arbitrary distribution of doping densities.	H. L. Armstrong
A Nuclear Reactor Control System	IRE Trans Ind Elec Jan 1959	Electronic equipment protects against dangerous power excursions and periods. Transistorized circuits provide reliability.	D. J. Niehaus R. R. Hoge A. B. Van Rennes
A High-Speed Low-Level Scanner	IRE Trans Ind Elec Jan 1959	Description of equipment that scans 500 pairs of strain-gage inputs at a repetition rate of 50 pairs per second. Uses transistor driver circuit.	K. Enslein
A UHF Solid-State Maser.	IRE Trans on Micro Theory & Tech Jan 1959	Chromium doped cobalticyanide has been utilized in the design and construction of a solid state maser operating between 300 to 500 *mc*.	R. H. Kingston
Solid State Microwave Amplifiers.	IRE Trans on Micro Theory & Tech Jan 1959	Review of the method of operation of these amplifiers, performance achieved and utilization of low-noise figures available.	H. Heffner
Low Noise in Solid State Parametric Amplifiers At Microwave Frequencies	Jl of App Physic Jan 1959	Principles of parametric amplifiers are described using low-frequency circuits and their mechanical analogs.	W. E. Danielson
Electroluminescent Thin Films	Jl of App Physics Jan 1959	Films of ZnS:Cu, Cl and ZnS:Cu, Mn, Cl have been made by a two-step evaporation-firing process.	W. A. Thornton
Grain Boundary Photovoltaic Cell	Jl of App Physics Jan 1959 (letter to Ed)	A photovoltaic cell is described which is a sensitive to light spot movement in two dimensions.	R. K. Mueller R. L. Jacobson
Preparation of Indium Arsenide	Jl of App Physics Jan 1959 (letter to Ed)	Arsenic purification and preparation of InAs discussed.	R. H. Harada A. J. Strauss
Magnesium-Bismuth Oxide Dry Cells.	Jl Electrochem Soc. Jan 1959	Construction and performances characteristics of magnesium-bismuth oxide dry cells are described.	C. K. Morehouse R. Glicksman
A Method for the Purification of Selenium	Jl Electrochem Soc. Jan 1959	Method is based on the formation and decomposition of hydrogen selenide. Details of apparatus of production given.	S. Nielsen R. J. Heritage
Particle Size Effect and the Distribution of Barriers in Electroluminescent Zinc Sulphide Phosphors	Jl Electrochem Soc. Jan 1959	Particle size is found to be a significant factor in empirical equations describing brightness-voltage relationships.	P. Goldberg
Activation of ZnS and (Zn, Cd)S Phosphors by Gold and Other Elements	Jl Electrochem Soc. Jan 1958	Linear relations in the peak locations and an energy diagram are discussed.	S. T. Henderson P. W. Ranby M. B. Halstead
A Comparison of the Theory of Impact Ionization With Measurements on Silicon P-N Junctions.	Jl Elec & Control (Brit) Jan 1959	The equations for the generation rate of electrons and holes by impact ionization in step *p-n* junctions have been derived in a more exact form.	F. W. G. Rose
The Electrical Conductivity and Hall Coefficient of Bismuth Telluride	Jl Elec & Control (Brit) Jan 1959	Variation of electrical conductivity and Hall coefficient of a number of specimens of Bi_2Te_3 over a wide range of doping concentrations.	B. Yates
Galvanomagnetic Properties of Gallium at Low Temperature	Physical Review Jan 1 1959	The galvanomagnetic properties of gallium single crystals in a transverse magnetic field have been investigated at helium temperatures.	J. Yahia J. A. Marcus
Infrared Properties of Cubic Silicon Carbide Films	Physical Review Jan 1 1959	Films of cubic silicon carbide have been grown by the reaction of methane with a high-purity silicon surface at 1300° C.	W. G. Spitzer D. A. Kleinman C. J. Frosch
Infrared Properties of Hexagonal Silicon Carbide	Physical Review Jan 1 1959	Infrared transmission and reflectivity measurements have been made on several samples of green alpha (hexagonal) SiC.	W. G. Spitzer D. A. Kleinman D. Walsh
Structure of Deuteron-Irradiated Germanium	Physical Review Jan 1 1959	The structure of deuteron-irradiated germanium is discussed in the light of recent experiments.	F. L. Vook R. W. Balluffi
Length and Resistivity Changes in Germanium Upon Low-Temperature Deuteron Irradiation and Annealing	Physical Review Jan 1 1959	The annealing after successive irradiations showed a gradual recovery of the expansion which was observable.	F. L. Vook R. W. Balluffi
Low-Temperature Luminescence and Photoconductivity of AgCl	Physical Review Jan 1 1959	The decrease of the luminescence intensity with increasing temperature can be attributed to a competing recombination process.	D. A. Wiegand

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Specific Heat of Germanium and Silicon at Low Temperatures	Physical Review Jan 1 1959	The specific heats measured are in very good agreement with older results, with some slight variations.	P. H. Keesom G. Seidel
Zeeman-Type Magneto-Optional Studies of Inter-band Transitions in Semiconductors	Physical Review Jan 1 1959	In the presence of a magnetic field the quasi-continuous levels of simple energy bands are coalesced into one dimensional sub-bands.	E. Burstein G. S. Picus R. F. Wallis F. Blatt
Hall Effect for Electrons in Silver Chloride	Physical Review Jan 15 1959	The Hall mobility of photoelectrons has been measured down to 5°K in single crystals of silver chloride.	K. Kobayshi F. C. Brown
Conductivity of Grain Boundaries in Grown Germanium Bicrystals.	Physical Review Jan 15 1959	The conduction of current in the grain boundary of a grown germanium bicrystal has been studied as a function of doping.	B. Reed O. A. Weinrich H. F. Matare
Power Measurements at 4 Gc/s by the Application of the Hall Effect in a Semiconductor	Proc Inst of EE (Brit) Jan 1959	Use of a resonant cavity with the crystal located at a point of strong magnetic field forms basis of wattmeter described.	L. M. Stephenson H. E. M. Barlow
The Reactatron-A Low-Noise Semiconductor Diode, Microwave Amplifier	Proc IRE Jan 1959	Amplifier uses two non-linear capacitor microwave *p-n* junction diodes in a balanced hybrid system.	F. A. Brand G. W. Matthei T. Saad
A Feedback Light-Amplifier Panel for Picture Storage	Proc IRE Jan 1959	A transient input image can be stored for an indefinite time as a black-and-white or on-off picture on a light-amplifier panel incorporating feedback.	B. Kazan
Photoelectronic Circuit Applications.	Proc IRE Jan 1959	Study of properties of photoelectric devices and of the applications of these elements to the design of switching circuits.	S. K. Ghandi
A Semiconductor Current Limiter	Proc IRE Jan 1959	Two-terminal constant-current device employs the principles of the field effect transistor.	R. M. Warner Jr. W. H. Jackson E. I. Doucette H. A. Stone Jr.
Large Scale Preparation of Ultra-Pure Silicon.	Res Appd in Ind Mar 1959	Difficulties in preparation, methods of preparation du Pont process, iodide process, reduction of $SiCl_4$ and $SiHCl_3$, purity of product, and Silane process are discussed.	J. M. Wilson
Large Scale Preparations of Ultra-Pure Germanium	Res Appd in Ind Feb 1959	Occurence, properties, extraction, and final production of intrinsic germanium described.	J. M. Wilson
Power Transistors	Res Appd in Ind Jan 1959	Features of the electrical and mechanical design of power transistors are discussed.	D. S. Grant R. O. Jones T. Scott
Transistor Switching Circuits, Part I	Semiconductor Products Jan. 1959	Description, formulas, precautions, and circuits that may be required by the design engineer.	A. W. Carlson
A Glass Transistor Enclosure	Semiconductor Products Jan. 1959	Basic technique that was used to make an all-glass enclosure possible is described.	R. K. Whitney
Transistor Thermal Stability	Semiconductor Products Jan. 1959	The thermal stability of a transistor connected in a general bias circuit, with no signal applied is analyzed.	M. J. Hellstrom
Transistor Characterization at VHF	Semiconductor Products Jan. 1959	A technique for the characterization of transistors in the common emitter configuration at VHF (30-300 mc).	R. P. Abraham R. J. Kirkpatrick
Effects of Nuclear Radiation on Semiconductor Materials and Devices	US Govt Res Rep Jan 16 1959 Order LC PB134674	Methods by which nuclear irradiation produces defects in semiconductor materials.	R. D. Larson
Cadmium Sulfide Solar Generator	US Govt Res Rep Jan 16 1959 Order OTS PB151276	The efficiency of CdS photovoltaic cells has been increased to a range of 3 to 5%. Cells described give 50 *mw* at 6 to 7V.	D. A. Hammond F. A. Sherland R. J. Baughman
Transistor Admittance Measurements in the 0.1 to 5 MC Range.	US Govt Res Rep Jan 16 1959 Order LC PB134634	Report covers the modifications of the Wayne-Kerr *r-f* Admittance Bridge Type B-601 to measure admittance parameters.	G. N. Kamboures
Analysis and Applications of a Variable Capacitance Junction Diode.	US Govt Res Rep Jan 16 1959 Order LC PB134835	Result of attempt to explore the possible uses for the capacitance found in *p-n* junctions.	L. Roesler
Performance of Transistors in Video Amplifiers	US Govt Res Rep Jan 16 1959 Order LC PB133817	Detailed theoretical data are presented on the performance of 2N139, TA-E1579, SB-100, and 2N104 transistors in video amplifiers.	J. A. Prugh

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from Dec. 27, 1955 to May 15, 1956. In subsequent issues, patents issued from May 15, 1956 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear periodically, the treatment given to each item being more detailed.

December 27, 1955

2,728,857 Electronic Switching—G. C. Sziklai. Assignee: Radio Corporation of America. An electronic switching system including a semiconductor device of the *n-p-n* type, a control circuit, a utilization circuit, and means for reversing the direction of flow of current in said control circuit to control the opening and closing of said utilization circuit.

2,728,881 Asymmetrically Conductive Devices—G. T. Jacobi. Assignee: General Electric Company. An asymmetrical conducting device comprising a spherically-shaped semiconductor member, a first electrode in large area contact with said semiconductor, and a second electrode making small area tangential contact with said semiconductor.

January 10, 1956

2,730,576 Miniaturized Transistor Amplifier Circuit—R. S. Caruthers. Assignee: Bell Telephone Laboratories. An object of this invention is to effect a radical space saving in an amplifier circuit.

2,730,680 Wave Transmission Network Using Transistor—J. F. Bangert. Assignee: Bell Telephone Laboratories. A two-terminal negative-resistance network comprising two transistors, two resistive impedances at least one of which has a resistive component in the operating frequency range of the circuit, and a source of direct voltage.

January 17, 1956

2,731,561 Crystal Contact Devices—E. G. James, A. O. Lindell. Assignee: General Electric Company Ltd. A crystal contact device for use at millimeter wavelengths comprising a wave guide section, a crystal element and a metal whisker in contact with said element, mountings for said crystal and said whisker, and a coaxial output coupling electrically connected to said crystal and said whisker.

2,731,567 Transistor Relaxation Oscillator —G. C. Sziklai, W. S. Pike. Assignee: Radio Corporation of America. A circuit comprising a semiconductive device, an impedance element connected to the emitter of said device, and a storage element connected between the collector and an intermediate point on the impedance element.

2,731,571 Delay circuit—B. Chance. Assignee: United States of America (Navy Department). A circuit having first and second input and output terminals, a capacitor connected between said first and second input and output terminals respectively, said second input and output terminals being connected together, a first germanium crystal and a source of biasing voltage connected in series between the first and second output terminals, and a second germanium crystal connected between the first input and output terminals in parallel with the first crystal and a voltage source.

January 24, 1956

2,732,519 Method of Making Transistors and Assembly Thereof—G. Freedman. Assignee: Raytheon Manufacturing Company. An assembly comprising an *n*-type impurity element selected from the fifth perodic group, means for changing a section to the *p*-type state and leads connecting said section to said body.

January 31, 1956

2,733,303 Bidirectional Amplifiers—W. Koenig, Jr. Assignee: Bell Telephone Laboratories. A four terminal network for interconnecting a pair of external networks, having as one design objective the achievement of the advantages of push-pull operation in a bidirectional amplifier without the necessity of either center-taps in input and output transformers.

2,733,304 Bidirectional Amplifiers—W. Koenig, Jr. Assignee: Bell Telephone Laboratories. A bilateral amplifier for interconnecting a pair of external circuits comprising a pair of transistors; means for connecting together a pair of unlike electrodes, one from each transistor; means for connecting one of said external circuits to a pair of electrodes different from the former pair; means for connecting the second external circuit to the remaining pair of electrodes.

2,733,390 Germanium Rectifier For Large Currents—W. E. Scanlon. Assignee: None. A rectifier comprising a germanium wafer having a conducting plate secured to one face thereof with tin solder, a conducting lead secured to the opposite face with indium solder, said tin solder and said indium solder diffusing into said wafer to form *n*-type and *p*-type germanium respectively.

February 7, 1956

2,734,102 Semiconductor Devices—J. I. Pankove. Assignee: Radio Corporation of America. A device comprising a flat-faced body of semiconductive material, a large area contact with said body, at least four further metallic wire electrodes providing line contact with said semiconductor.

2,734,154 Semiconductor Devices—J. I. Pankove. Assignee: Radio Corporation of America. A device comprising a semiconductive body and conductive fluid electrode in contact therewith.

2,734,164 Current Supply Regulating Apparatus—C. S. Knowlton. Assignee: Bell Telephone Laboratories. Apparatus for supplying alternating current from a supply source to a load circuit including a load comprising a saturable transformer, an *n-p-n* transistor, a *p-n-p* transistor, and means for deriving from said load circuit and impressing between the base and emitter of each transistor an alternating voltage which varies in response to changes of the alternating load voltage.

February 14, 1956

2,735,011 Oscillating Circuit—A. H. Dickinson. Assignee: International Business Machine Corporation. An oscillation generator utilizing an electron tube, a crystal triode coupled serially thereto, and a capacitor coupled across the crystal triode, the capacitor being charged through said triode with one value of current, and discharged through said triode with a different value of current.

2,735,049 Transistor—L. de Forest. Assignee: None. A device including base, emitter, and collector, and in order of physical arrangement a layer of electron-multiplier material on said collector; a conducting layer; a second electron-multiplier layer; a layer of cathodoluminescent material; and a light transparent electrically conducting member.

2,735,091 Anti Key-Bounce Circuit—W. H. Burkhart. Assignee: Monroe Calculating Machine Company. In an anti key-bounce keyboard circuit; a first and second potential source; a plurality of front and back contact keys in a series path *between* the first and second sources; a plurality of signal lines selectively connectable to said first source; a flip-flop connected to each line and set to one state on application thereto of the potential of the first source; and means for resetting said flip-flop to the opposite state.

February 21, 1956

2,735,919 Photo-Transistor and Method of

* Source: Official Gazette of the U. S. Patent Office and Specifications and Drawings of Patents Issued by the U. S. Patent Office.

Manufacture—E. G. Shower. Assignee: National Union Electric Corporation. A method which comprises melting a piece of transistor impurity material to a localized region of a semiconductor to form a photo-transistor alloy junction, attaching a lead in wire, slicing through said junction between the margin and the lead wire contact point to form a flat exposure phototransistor surface.

2,735,948 Multielement Semiconductor Devices—G. C. Sziklai. Assignee Radio Corporation of America. A device comprising a semiconductor body having four alternating regions of a *p*-type and *n*-type conductivity, regions I and IV being biased in the forward direction with respect to adjacent regions; and a plurality of transverse channels formed in said body and intersecting an alternate arrangement regions I, II, and III; and then II, III, and IV.

February 28, 1956

2,736,639 Surface Treatment of Germanium—R. C. Ellis, Jr. Assignee: Raytheon Manufacturing Company A method for improving the electrical characteristics of germanium bodies by subjecting them to a fluid mixture from which excess germanium is readily reclaimable.

2,736,672 Selenium Rectifier of Increased Blocking Properties—O. Klein. Assignee: International Standard Electric Corporation. A selenium rectifier having on the base electrode, a second coating of selenium, said second coating containing an alkaline metal and a crystallization-retarding substance taken from the class consisting of arsenic and phosphorous.

2,736,822 Hall Effect Apparatus—W. C. Dunlap, Jr. Assignee: General Electric Company. A device designed to provide a Hall effect apparatus in which the level of output Hall effect voltage may be adjusted to any desired magnitude for a given input Hall plate current and a given magnetic field strength, and capable of producing an output voltage which varies in response to the variations of three input electric signals.

2,736,843 Alternating Current Electromagnets—J. F. Douglas, A. F. Kolb. Assignee: Cutler-Hammer Incorporated. In an *a-c* electromagnet, rectification means, (utilizing a dry plate rectifier bridge) of supplying unidirectional power to shaded pole windings, said windings being so wound and so disposed and connected to said rectifier, that induced alternating voltages are effectively cancelled.

2,736,847 Fused-Junction Silicon Diodes—S. H. Barnes Assignee: Hughes Aircraft Company. A device comprising a silicon crystal element having an acceptor-impurity-doped *p*-type region, an antimony-doped *n*-type region separated from the *p*-type region by a rectifying barrier; and a hermetically sealed vitreous tubular envelope containing the assembly.

2,736,848 Photocells—A. Rose. Assignee: Radio Corporation of America. A photo conductive cell comprising a body of cadmium sulphide, two metallic electrodes one of which makes point-contact with a surface layer of said body, the interior of said body containing donor impurities and the surface of said body containing acceptor impurities.

2,736,849 Junction-Type Transistors—R. W. Douglas, J. W. Ryde. Assignee: Hazeltine Research Incorporated. A device consisting of two members, one of which has an *n*-type region and a *p*-type region with a predetermined surface, the second member of said device composed of *n*-type material with a predetermined surface of area less than that of the first mentioned surface; said surfaces being joined by heat and pressure bonding.

2,736,850 Selenium Rectifier Containing Tellurium—E. Ledow. Assignee: None. A selenium rectifier the semiconducting layer of which contains 90 to 1200 parts of tellurium and 1,000,000 parts of rectifier-type selenium by weight.

2,736,858 Controllable Electric Resistance Devices—H. Welker. Assignee: Siemens Schuckertwerke Aktiengesellschaft. A device consisting of an elongated semiconductive body having two differently textured surface areas oppositely placed, one of two said areas having an etched surface texture for reduced surface recombination, and the other of said surface areas having an etched surface texture for increased surface recombination.

March 6, 1956

2,737,587 Transistor Multivibrator—R. B. Trousdale. Assignee: General Dynamics Corporation. A transistor multivibrator circuit in which the frequency of operation is independent of the base circuit impedance of the transistors used in the circuit and is also independent of the fluctuations in the voltage applied to the circuit.

2,737,618 Miniature Rectifier—J. Eisler. Assignee: International Rectifier Corporation. A miniature selenium rectifier enclosed by a sleeve of stretchable insulating material, said sleeve pressing the components together, and a solid insulating envelope embedding and holding together the sleeve and the assembly.

March 13, 1956

2,738,259 Surface Treatment of Germanium —R. C. Ellis, Jr. Assignee: Raytheon Manufacturing Company. Improving the electrical characteristics of a germanium body by treating the surface of said body with a fluid mixture from which excess germanium is readily reclaimable.

March 20, 1956

2,739,190 Transistor Amplifiers and Circuit Arrangements Therefor: R. L. Wallace. Assignee: Bell Telephone Laboratories. A device comprising a transistor, an output circuit between the emitter and collector, an input circuit between the base and the emitter or collector, and including an unbypassed condenser and an input source, said input circuit having series connected impedances and presenting an infinite impedance to steady currents.

March 27, 1956

2,740,076 Crystal Triodes—K. A. Matthews, C. de Boismaison White. Assignee: International Standard Electric Corporation. A semiconducting body of one conductivity type having on a surface thereof a layer of the opposite conductivity type, a second layer of the original material on the first layer, a base electrode and two rectifying contact electrodes.

April 3, 1956

2,740,837 Semiconductor Signal Translating Devices—W. S. Kirkpatrick. Assignee: Bell Telephone Laboratories. A system comprising a plurality of elements variable as to conductivity under bombardment by charged particles, means to cause a beam of charged particles to impinge on any of said elements, and a source of unmodulated carrier potentials for varying the energy content of the beam thus varying the conductivity of said elements and causing modulation products to be produced in a circuit interconnecting all of said elements.

2,740,901 Differential Photocell Using Junction Semiconductors—R. E. Graham. Assignee: Bell Telephone Laboratories. A device comprising a semiconductor element having a narrow zone of one conductivity type between and contiguous with two outer zones of the opposite type, means for directing against the body of said element a light beam having a distribution characteristic which matches in shape the integral of the sensitivity characteristic g(x) of said material, where g(x) is a plot of voltage vs. light position of the spot with respect to the intermediate zone of said semiconductor element.

April 3, 1956

2,740,940 High Speed Negative Resistance—J. A. Becker, M. C. Waltz. Assignee: Bell Telephone Laboratories. A signal translating combination exhibiting a dynamic negative resistance at frequencies in the kilocycle range consisting of a germanium body containing at least 0.1 atomic per cent of donor and acceptor impurities in near balance.

April 10, 1956

2,741,686 Electric Resistor—H. Q. North, M. E. Kershaw. Assignee: General Electric Company. In a high frequency germanium diode, means for stabilizing the characteristics of the point-contact by pressing the electrode point against the surface of the germanium pellet with a force of between 50 and 150 mg. while passing a current between 50 *ma* and 250 *ma* of direct current in the forward direction from the electrode to the pellet.

2,741,729 Electrical Translating Device—H. Q. North. Assignee: Hughes Aircraft Company. A device comprising an assembly of crystal and contacting elements, a solidified insulating material surrounding and pervading all parts of the assembly except for a cavity encompassing said elements, and means for providing external connections.

2,741,758 Magnetic Core Logical Circuits—S. R. Cray. Assignee: Sperry Rand Corporation. The device provides a combination of magnetic and rectifier elements which comprise a basic circuit component which in various arrays may make up the complete control and arithmetic section of an electronic digital computer.

April 17, 1956

2,742,383 Germanium Junction—Type Semiconductor Devices—S. H. Barnes, J. N. Carman. Assignee: Hughes Aircraft Company. In a translating device: a germanium specimen having an indentation therein with an *n*-type region adjacent to said indentation, a *p*-type region adjacent to said *n*-type region, and a button filling said indentation, said button consisting of arsenic, gallium, and at least one element in which germanium is soluble.

2,742,571 Junction Transistor Oscillator Circuit—G. B. Herzog. Assignee: Radio Corporation of America. An oscillator including a transistor which exhibits a negative resistance characteristic over a portion of its operating range, and means providing a frequency determining circuit for said oscillator.

2,742,601 Constant Voltage Source—J. F. Hyland. Assignee: Minneapolis-Honeywell Regulator Company. A source comprising an *a-c* voltage source, a load, a rectifying circuit providing a regulated voltage across said load, and a second rectifying circuit providing an unregulated voltage across said load, said unregulated voltage being of polarity opposite to that of the regulated voltage.

2,742,602 Excitation Control for Synchronous Dynamo Electric Machines—E. W. Krebs. Assignee: None. An excitation control system for maintaining a predetermined interrelation of power factor, load, and terminal voltage of an *a-c* dynamo electric machine, said system including a bridge rectifier utilizing selenium elements and having a threshold voltage below which insufficient current will flow in the field windings of said machine to cause self-excitation thereof.

April 24, 1956

2,743,199 Process of Zone Refining An Elongated Body of Metal—F. C. Hull, P. H. Brace, G. Comenetz, A. W. Cochardt. Assignee: Westinghouse Electric Corporation. A process of zone refining an elongated solid body of metal without subjecting any of the metal melted during the process to contact with a foreign body.

2,743,200 Method of Forming Junctions in Silicon—N. B. Hannay. Assignee: Bell Telephone Laboratories. A method of forming a *p-n* junction in monocrystalline silicon comprising the steps of lowering a silicon seed crystal into a melt containing a conductivity type determining impurity, lifting material up from the melt to form an increasing length of crystal, and heating the crystal to change the conductivity type of portions thereof.

2,743,201 Monatomic Semiconductor Devices—R. P. Johnson, R. S. Shulman, D. M. Van Winkle. Assignee: Hughes Aircraft Company. A method of producing *p-n* junction devices comprising the steps of placing a coarse-surfaced semiconductor in contact with a smooth-surfaced semiconductor stressing the two specimens, and then heating said specimens to cause fusion in the contact region thereof.

2,743,322 Solid State Amplifier—J. R. Pierce, H. Suhl. Assignee: Bell Telephone Laboratories. In combination, an element exhibiting a large Hall effect, means for propogating signal electromagnetic waves axially through said element, means for creating a *d-c* electric field axially along said element, said *d-c* field and the magnetic field of said wave interacting to provide a Hall effect field which in turn combines with the electric field of said wave to provide amplification thereto.

2,743,420 Testing Semiconductor Rectifiers —W. F. Haldeman. Assignee: None. A method of grouping semi-conductor-type current rectifiers according to their current carrying exponential function of resistance defined by the expression . . . . $I^{-a} = bR$ . . . where I is the current, R is resistance, b is a conductance constant and a is a constant exponent of said function.

May 1, 1956

2,743,506 Method of Manufacturing Rectifier Cells—B. Solow. The invention provides a method of and a machine for manufacturing rectifier cells from laminated selenium sheets.

2,744,198 Transistor Trigger Circuits—G. Raisbeck. Assignee: Bell Telephone Laboratories. A circuit for generating output waves of symmetrical form comprising a pair of signal translating devices having voltage-current characteristics which are similar in shape but opposite in sign.

2,744,219 Bifilar Triode Transistor—H. J. McCreary. Assignee: Automatic Electric Laboratories. In a translating device a semiconductive element with a base electrode attached thereto, emitter and collector elements comprising finely insulated wires of small diameter arranged in a plurality of parallel contiguous rows of alternate collector and emitter elements.

May 8, 1956

2,744,308 Semiconductor Translating Device and Method of Manufacture—G. T. Lowman. A method of making semiconductor translators consisting of securing a thin resilient metal plate on an insulating support member to at least two points, severing the plate to form two independent sections, bending opposed portions of the sections out of the plane of the plate, and contacting a semiconductive surface with the edges of said portions.

2,744,970 Semiconductor Signal Translating Devices—W. Shockley. Assignee: Bell Telephone Laboratories. A semiconductive body including a first zone of one conductivity type separated from a second zone of the opposite conductivity type by a rectifying junction, means for discouraging minority carrier injection from the second zone into the first zone, and means for supplying majority carriers to the first zone from a source connection, and collecting said majority carriers from said first zone to a drain connection.

2,745,009 Highly Stable Transistor Oscillator—J. M. Moulon. Assignee: None. A high stability transistor oscillator including a two-stage transistor amplifier including a phase inverting interstage transformer, a phase inverting output transformer and input and output stage transistors.

2,745,010 Transistor Oscillators—F. R. Stansel. Assignee: Bell Telephone Laboratories. An oscillator comprising a transistor, a frequency-determining impedance connected between the emitter and collector, and an amplifier having its input side connected in series with said impedance in the path between said emitter and collector.

2,745,012 Transistor Blocking Oscillators—J. H. Felker. Assignee: Bell Telephone Laboratories. A pulse generator comprising, a transistor, a timing capacitor with a charging path that includes the internal path of said transistor between the emitter and base electrodes, and a discharge path that includes a resistor connected between the emitter and the base electrodes, said capacitor being charged and discharged in order to provide sharp pulses of output voltage.

2,745,021 Photo-Device Amplifier Circuit—J. Kurshan. Assignee: Radio Corporation of America. An amplifier circuit for a photoconductive device comprising a photoconductive device having a non linear resistance, a transistor, and a first source of potential providing maximum base current, whereby the collector current decreases in response to illumination of said photo-conductive device.

2,745,038 Semiconductor Signal Translating Circuit—G. C. Sziklai. Assignee: Radio Corporation of America. A circuit consisting of a pair of transistors of opposite conductivity type, means for applying an *a-c* signal to the electrodes thereof, an image reproducing device including a control electrode and a cathode, and output means coupling the output electrode of one of the transistors with said control electrode and coupling the ouput electrode of this other transistor with said cathode.

2,745,044 Asymmetrically Conductive Apparatus—F. J. Lingel. Assignee: General Electric Company. A sealed asymmetrically conductive device including a plurality of series connected semiconductor elements any one of which may be individually removed and replaced.

2,745,045 Semiconductor Devices and Method of Fabrication—R. C. Ingraham. Assignee: Sylvania Electric Products Inc. A semiconductor point-contact device enclosed by a rigid insulating body surrounding the assembly of the elements thereof.

2,745,046 Alloys and Rectifiers Made Thereof—K. Lark-Horovitz, R. M. Whaley. Assignee: Purdue Research Foundation. Semiconductor devices made from alloys of 99% pure germanium and at least one of the elements from the cobalt nickel group; and alloys made from 99% pure germanium and an amount of palladium up to 0.50 atomic per cent.

2,745,047 Selenium Rectifiers and Method of Manufacture—P. E. Lighty. Assignee: International Telephone and Telegraph Company—In the method of making selenium rectifiers containing adjacent layers of nickel and selenium, the steps comprise producing a layer of nickel selenide at the interface of the nickel and selenium layer by heating said layers to a temperature of 500°C.

2,745,068 Transistor Negative Impedance Converters—D. K. Gannett. Assignee: Bell Telephone Laboratories. A device designed to insure that the conversion factor of a transistor negative impedance converter is substantially a numeric over the frequency range of interest.

May 15, 1956

2,745,960 Semiconductor Signal Generator —B. D. Griffith. Assignee: Radio Corporation of America. A feedback sine wave oscillation generator of the resistance capacitance type including a point-contact type transistor, and means for varying the current in the emitter electrode in order to vary the generator's frequency of oscillation.

2,745,973 Radioactive Battery Employing Intrinsic Semiconductor—P. Rappaport. Assignee: Radio Corporation of America. A primary source of electrical energy comprising a semiconductive body having a resistivity in or near the intrinsic region a *p*-type region formed at one surface of said body, an n-type region formed at the opposite surface, a source of nuclear emission for irradiating said body to establish a difference in electrical potential between said regions, and means for supplying the energy of said potential to a load circuit.

[To Be Continued]

NEW SPECIAL DIODES CHARTS

CHARACTERISTICS CHARTS OF SILICON ZENER OR AVALANCHE DIODES

TYPE NO.	Zener or Avalanche Voltage Range			Dynamic Impedance		MAX. DISS.	TEMP. CO-EF-FICIENT	MFR. (See code at start of chart)
	MIN. E_{b1} (volts)	MAX. E_{b2} (volts)	@ I_z (ma)	Z @ I_z (ohms)	(ma)	(mw)	%/°C	
1N821	5.9	6.5	7.5	15	7.5	250	.01	TRA
1N822⍁	5.9	6.5	7.5	15	7.5	250	.01	TRA
1N823	5.9	6.5	7.5	15	7.5	250	.005	TRA
1N824⍁	5.9	6.5	7.5	15	7.5	250	.005	TRA
1N825	5.9	6.5	7.5	15	7.5	250	.002	TRA
1N827	5.9	6.5	7.5	15	7.5	250	.001	TRA
HPZ8.2	7.5	9.1	1000	.50	1000	25W	.04	USS
HPZ10	9.1	11	800	.60	800	25W	.056	USS
HPZ12	11	13	700	.80	700	25W	.058	USS
HPZ15	13	16	550	1.0	550	25W	.06	USS
HPZ18	16	20	450	1.5	450	25W	.062	USS
HPZ22	20	24	400	2.0	400	25W	.064	USS
HPZ27	24	30	350	3.0	350	25W	.066	USS
HPZ33	30	36	270	5.0	270	25W	.068	USS
HPZ39	36	43	200	7.0	200	25W	.070	USS
HPZ47	43	51	160	9.0	160	25W	.072	USS
HPZ56	51	62	140	12	140	25W	.075	USS
HPZ68	62	75	120	15	120	25W	.08	USS
HPZ82	75	91	100	18	100	25W	.086	USS
HPZ100	91	110	80	22	80	25W	.092	USS
OA2200	4.4	5.0	1.0	350	1.0	250	.043	MUL
OA2201	4.8	5.4	1.0	340	1.0	250	.035	MUL
OA2202	5.3	6.0	1.0	260	1.0	250	.027	MUL
OA2203	5.8	6.6	1.0	160	1.0	250	.016	MUL
OA2204	6.4	7.2	1.0	40	1.0	250	.044	MUL
OA2205	7.1	7.9	1.0	10	1.0	250	.053	MUL
OA2206	7.7	8.7	1.0	8.0	1.0	250	.067	MUL
OA2207	8.6	9.6	1.0	8.0	1.0	250	.071	MUL
OA2208	3.3	5.0	1.0			250		MUL
OA2209	4.4	6.0	1.0	340	1.0	250		MUL
OA2210	5.3	7.2	1.0	160	1.0	250		MUL
OA2211	6.4	8.7	1.0	10	1.0	250		MUL
OA2212	7.7	10.6	1.0	8.0	1.0	250		MUL
OA2213	9.4	15	1.0			250		MUL
XD1	9.0	13	20	26	20	800	.07	TI

Under Type Number

⍁ - Double Anode Type

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f (mA)	@ E_f (volts)	Reverse Impedance @ 25°C Z (K ohms)	VOLTAGE RANGE E_{b1} to E_{b2} (volts)	Recovery Characteristics TEST CONDITIONS Fwd. I_f (ma)	Rev. E_b (volts)	$Z_{rec.}$ @ time (t) (K ohms)	(usec)	MFR. (See code at start of charts)
1N806	Si	110	100	4.0	1.0	200M	100	5.0	40	400	.30	TRA
1N807	Si	200	175	4.0	1.0	350M	175	5.0	40	400	.30	TRA
1N808	Si	110	100	100	1.0	100M	100	30	35	100	.30	TRA
1N809	Si	220	200	100	1.0	200M	200	30	35	100	.30	TRA
DR664	Si	30	25	20	1.5			5.0	15	30	.25	GIC
DR667	Si	250	200	100	1.0			5.0	40	80	.30	GIC
DR883	Si	200	175	5.0	1.5			5.0	40	400	.30	GIC
OMC113	Ge	100	75	200	1.0			5.0	40	400	.20	OHM
OMC118	Ge	100	75	200	1.0			5.0	40	400	.50	OHM
OMC213	Ge	100	75	100	1.0			5.0	40	400	.30	OHM
OMC218	Ge	100	75	100	1.0			5.0	40	400	.55	OHM
OMC351	Ge	100	75	40	1.0			5.0	40	25	1.0	OHM

TURN TO PAGE 54 FOR MISCELLANEOUS DIODE TYPES

New Products

Tantalum Capacitors

A completely new high reliability line of *tan-TI-cap* solid tantalum capacitors Type SRM, was announced recently by Texas Instruments. Performance specifications require rated voltage operation at temperatures from −55 to +85°C, and at +125°C for 2000 hours. Features include subminiature industry standard case sizes, a continuous reverse voltage capability, nominal voltage derating required for 125°C operation, high vibration and shock resistance, hermetic seals and a high corrosion-resistant finish. Supported axial leads without external welds permit ease of mounting and can be sharply bent without breaking.

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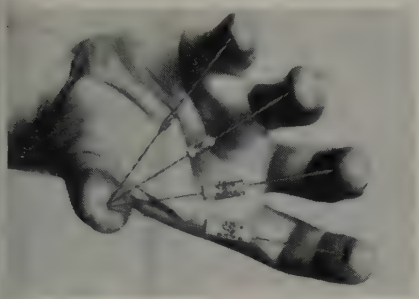

Aluminum Spheres

High purity aluminum spheres are available to semiconductor manufacturers for use in forming alloy junctions in silicon devices, from Accurate Specialties in sizes from .004" diameter to .125" diameter. Some advantages over conventional washers or discs: the sphere will offer the least amount of oxide per unit volume since it represents the smallest surface per unit volume; a precision sphere can roll, and therefore lends itself to automatic loading into the alloying jigs.

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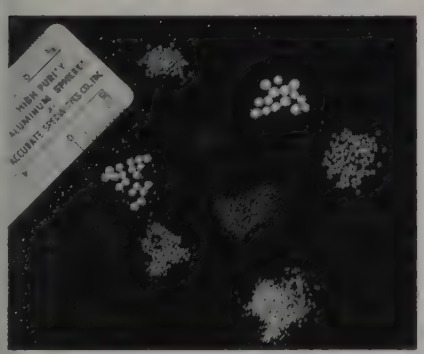

Mobile Industrial Ultrasonic Cleaner

A mobile ultrasonic cleaning system, mounted on rubber-tired wheels, is now being manufactured to order by Acoustica Associates, Inc. The units can be easily pushed from one location to another for use wherever electric power is available. Cleaning tanks up to 75 gallons capacity and ultrasonic power generators in ratings up to 2500 watts can be provided. Power may be derived from a 115-volt or 220-volt a-c outlet.

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Vacuum Chamber

For testing and conditioning transistors, capacitors, and other semiconductors, Electric Hotpack vacuum ovens have ambient ranges to 200 and 300°C. Chamber capable of evacuation to 1 micron. Heaters placed on all sides for constant, uniform temperatures. Square design utilizes all interior space for work load. Full view window permits 100% visibility. Standard units may be equipped with through wall connections, lead wires, or terminals for the test articles; or with doors on both sides of the cabinet for use on production lines.

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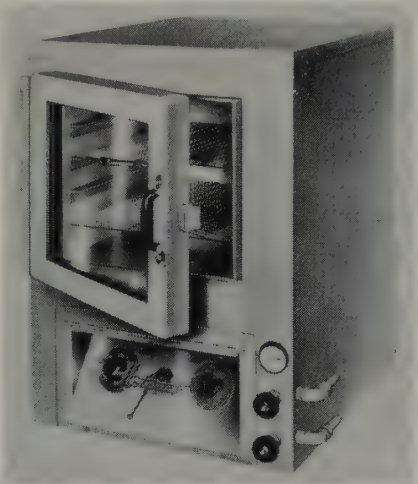

Silicon Diodes

Continental Device Corporation announces a new series of silicon diodes manufactured by the Controlled Fusion Technique which effects precise control over the junction formation and geometry and leads to very uniform characteristics in production. Types CD1111 through CD1116 have working voltages through 300 volts and forward currents in excess of ¼ ampere at 1 volt. Reverse currents are below 5 millimicroamperes at the maximum working voltage. More conventional types such as the IN480 series and the IN456 through IN459 are also available.

Circle 79 on Reader Service Card

Automatic Hole Puncher

The principles of automatic production built into the new Kahle Engineering Company Automatic Hole-Punching Machine #3013 will quite likely find use in many industries where high-speed hole-punching and fire glazing are applied to glass units on any configuration. Has a capacity of 2000 sealed beam headlamp reflectors per hour; punches multiple preformed holes, fire-glazes the holes and unloads the reflectors to an annealer. Can be fully synchronized with the press to provide any timing cycle desired. The two-position punching operation performed at 2400 psi at 400° C can be altered to vary the hole pattern, number or size to suit manufacturers' specs. Occupies 5 × 5 ft. floor space, is 6'6" high, approx. 6000 lbs. Can be driven from the forming press or may be equipped with its own power drive. Request data sheet 3013.

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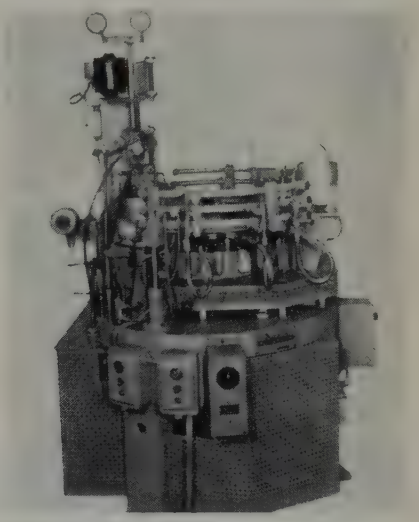

Drift Transistors

Three new drift transistors of the germanium p-n-p alloy type, 2N643, 2N644, and 2N645 are specifically designed for use in high-speed non-saturating switching circuits of electronic computers such as inverters, flip-flops, and logic gates where high gain-bandwidth product and pulse repetition rates up to 10 Mc are primary design requirements. Have hermetically sealed metal cases and the dimensions of the JEDEC TO-9 outline. From RCA.

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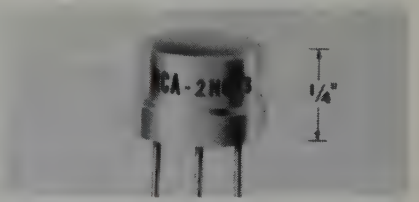

Lab & Production Tool

Kulicke & Soffia Mfg. Company introduces their new Micromanipulator for subminiature assembly with rugged construction, accurate movements, highload capacity, longlife service. Half inch movement in three planes to tenths accuracy. Features silky smooth backlash, free action, simple spring loaded ball and V ways. No special adjustments or fancy gibs. Cannot be damaged by overloads, excellent dimensional stability. One of a line of tool machines for semiconductor production.

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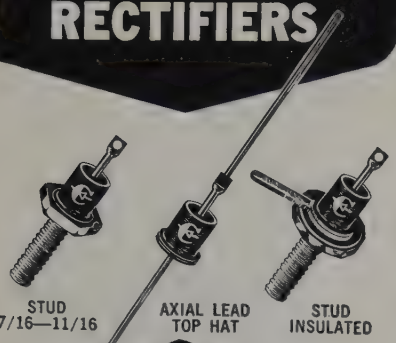
(Continued on page 56)

COLUMBUS ELECTRONICS CORP.

DOUBLE DIFFUSED SILICON RECTIFIERS



Now . . . an extensive line of high performance, hermetically sealed, silicon power rectifiers UP TO 35 AMPS. JEDEC types exceeding MIL specifications.

NEW

SINGLE unit VERY HIGH VOLTAGE silicon rectifiers exhibiting these desirable characteristics . . .

HIGH VOLTAGE up to 2000 PIV	LOW FORWARD DROP 1.5 Volts, DC
EXTREMELY LOW LEAKAGE 1 μA	FORWARD CURRENT up to 20 Amps.

NEW

INSULATED STUD silicon rectifiers offering these quality features . . .

- Simplify mounting
- Saves assembly parts & costs
- Obtain efficient heat transfer
- Give greater design flexibility

AVAILABLE UP TO 10 AMPS PER UNIT AND UP TO 2000 VOLTS PIV.

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BOOK REVIEWS . . .

TITLE: Transistor Technology Volume III

AUTHOR: Edited by F. J. Biondi

PUBLISHER: Van Nostrand

Transistor Technology, Volume III, is the final volume in the three part set. As in the other volumes the material is broadly divided into sections, each containing chapters containing a collection of many published and unpublished papers in addition to much unpublished material.

The first section is a basic treatment of the process of control of the donors and acceptors in silicon and germanium. There are chapters on junction formation, methods and purity control. The formation of junctions by diffusion is presented in terms of techniques and technology. The process is well described and clearly illustrated.

Section II outlines fabrication technology or the transformation of the crystal material into a device. Other methods of junction introduction such as alloying and diffusion are presented as adjuncts to the crystal growing process described in Part II of the first volume. General chemical processing with respect to all phases of transistor fabrication and etching techniques are described in Chapters IV and V. The alloying process is presented with the aluminum-silicon alloy diode defined and analyzed.

The final sections of the book are entitled Measurements and Characterization and Transistor Reliability. These sections are devoted to complete methods of transistor parameter measurements and reliability techniques. The IRE standards are followed, in general, and are tabulated in Appendix II. Many conculsions are drawn from the results of field reports and laboratory studies.

Transistor Technology Volume III is the concluding volume of a very comprehensive and current review of the field of transistor devices. The book, as are the others in the series, is accurate, concise, a virtual encyclopedia of information and will undoubtedly remain in demand as a textbook on the subject of transistors.

TITLE: Proceedings of the Symposium on the Role of Solid State Phenomena in Electric Circuits; VII

AUTHOR: Edited by Jerome Fox

PUBLISHER: Intersciene Publishers of New York

The Proceedings of the 1957 Symposium, sponsored by the Microwave Research Institute of the Polytechnic Institute of B'klyn, the IRE, and various military agencies had as its topic the uses and theories of solid state materials in electronic circuitry. This book is a collection of the various papers presented during the three day discussion.

The opening papers deal with descriptions of solid state materials and definitions of the solid state. Many devices are covered in the first paper by Harold. Although his treatment is basically nonmathematical, the descriptions are quite interesting particularly with respect to the maser, the semiconductor diode, and Hall effect devices. A later paper by Artman gives a very thorough treatment of the solid state maser with much original material.

There are several informative presentations on transistors and associated devices. Superconductivity applications are covered in a paper by McMahon. Ferrite materials and domain theory in core switching are also well treated. An article by Stern on harmonic generation and mixing in ferrites is an excellent review of the topic in the light of current developments.

The collection of these and many other papers as compiled in this seventh volume are of excellent technical content and well recommend this book as a reference of current practice in solid state theory and applications.

TITLE: An Introduction to Transistor Circuits

AUTHOR: E. H Cooke-Yarborough

PUBLISHER: Interscience Publishers, Inc.

An Introduction to Transistor Circuits is a primer on transistors written to introduce the engineer to the subject, where only a very basic understanding is required.

The first chapter entitled "Transistor Action" establishes the transistor as an outgrowth of the *p-n* junction diode. A vast amount of material is treated in a rather brief but understandable manner. Minority carrier injection, the junction diode, carrier storage, and the junction and point contact transistor are several of the topics discussed.

Chapters II and III introduce the transistor as an amplifying device in various circuit configurations. The low frequency equivalent circuit is shown and a comparison between the pentode vacuum tube amplifier is drawn. The presentation of the three circuit configurations is effected with a minimum of mathematical derivation from the usual equivalent circuits. Intuitive reasoning is used throughout and the explanations are simplified by the analysis of the *T*-equivalent circuit. The very familiar *h*-parameters are not mentioned, limiting the analysis somewhat, since most transistor parameters are presented in terms of the pi-equivalent circuit however, the understandability of the descriptions does not suffer. A chart of the expressions derived is included in Chapter II, with some algebraic manipulation designed to present the results in more familiar forms. *D-C* stability, coupled amplifiers, and circuit behavior complete Chapter III.

The balance of the book deals with various circuit applications of the transistor. Pulse circuits are dealt with in Chapter IV, and *d-c* converters, counting circuits and computer applications in Chapter VI. The style maintains the intuitive approach *i.e.* more suitable for the experimenter than the physicist.

An Introduction to Transistor Circuits is an interesting and well written book, and presents a slightly different approach to the understanding of the transistor. Although the circuit designer may find some difficulty in the direct application of the design techniques outlined (in view of the lack of consideration of a more useful equivalent circuit) the beginner will benefit much from the book.

Stephen E. Lipsky

Industry News

The Following August 1959 IRE and Jointly Sponsored Meetings are Scheduled:

August 17	1st National Ultrasonics Symposiums, San Francisco, California. For Information: Dr. Vincent Salmon, Stanford Research Institute, Stanford, California.
August 18-21	WESCON. Cow Palace. San Francisco, California. For Information: Dr. Karl Spangenberg, c/o Wescon, 60 W. 41st Ave., San Mateo, California.

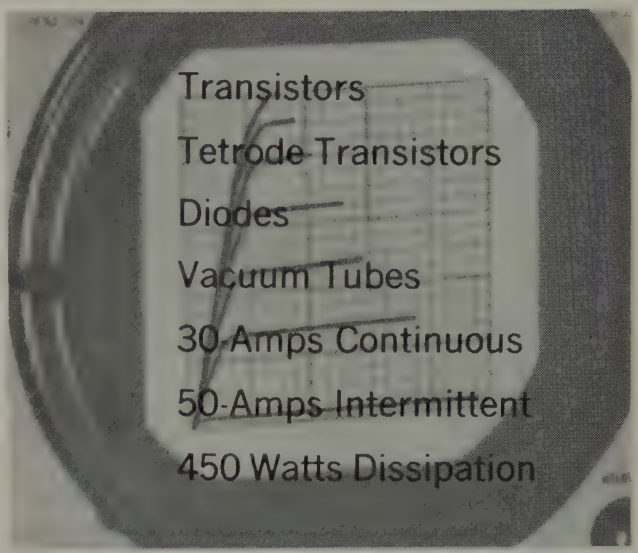
U. S. exports of electronic equipments and parts increased by nearly 10 percent between 1957 and 1958, according to the annual report of Chairman Ray C. Ellis, of the EIA International Department and Vice President of the Raytheon Co., Waltham, Mass. The report was submitted during the 35th annual convention of the Electronic Industries Association, May 20-22. Mr. Ellis pointed out that exports of electronic products were worth over $427 million in 1958, or nearly 6 percent of the industry's total production. The most spectacular increase was registered in the semiconductor field where exports jumped from 2.7 million units worth $4.2 million in 1957 to 5.8 million units worth $7.8 million in 1958. In addition to components used in end equipments direct 1958 exports increased to 40.6 million capacitors, 43.6 million resistors, 5.7 million inductors. The value of unclassified parts and accessories increased from $27.6 million in 1957 to $31.8 million in 1958. Over $27 million worth of electrical and electronic test and measurement equipment was exported; $17 million worth of electronic computers and related information processing machines and parts also went into the world market. Although the total volume of electronic exports declined slightly in the first quarter of 1959 it still accounted for $100 million worth of business during the period.

EIA Tube and Semiconductor Division chairman, D. W. Gunn, said in an annual report, delivered during the Association's 35th annual convention, that the semiconductor section is unquestionably the Division's largest and fastest-growing group. It was estimated that semiconductor sales reached $226 million in 1958. This compares with $172 million during 1957, or 19 percent of total valving device sales of $925 million. During the five year period beginning with 1954 and ending with 1958, the dollar value of transistor sales by factories has increased more than 20 times from $5.1 million to $112.7 million. The germanium silicon semiconductor diode-rectifier industry has increased during the same period nearly 4 times, from $20 million to $96 million.

Mr. Gunn stated it is possible that the $300 million mark for all semiconductors will be reached during 1959. By 1965, semiconductor manufacturers may well be sharing a $1 billion annual market He also emphasized the importance of controlling imports from abroad for the protection of the domestic industry.

Five hundred representatives of industry, colleges, engineering societies and the press in the New York City area gathered at a luncheon in the Hotel Astor to hear Walter

NEW CURVE TRACER with Tube Adapter



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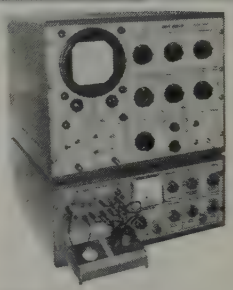

Baird Atomic

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Visit B/A booth at WESCON, Aug. 18-21

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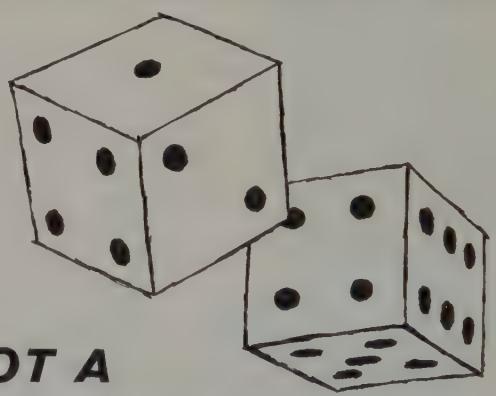


"GOT A DICING PROBLEM?"

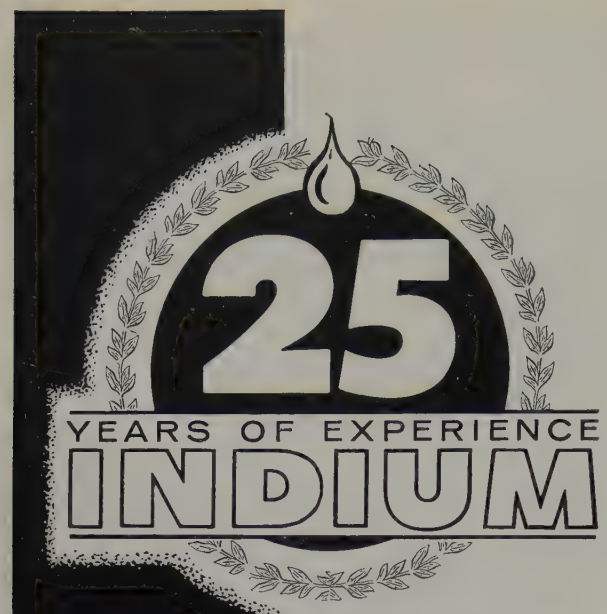
If dicing germanium or silicon slices is a production bottleneck with you, C.I.C.'s Dicing Service can help you overcome it.

We are specialists in ultrasonic machining of all types and have established a special dicing service to handle crystal wafers, either mounted or unmounted, efficiently and economically—overnight when required. In addition to ultrasonic grinders, we have complete toolmaking facilities.

Whether your dicing requirements are large or small, continuous or occasional, C.I.C.'s Dicing Service can expand your own facilities by any required amount. Write or phone us for full particulars.

CIC CONNECTICUT INSTRUMENT CORPORATION
Wilton, Connecticut
Telephone: POrter 2-5021

Circle No. 22 on Reader Service Card



1934-1959

- AIDS LUBRICATION
- UNIQUE STABILIZATION
- ALLOYS READILY

QUALITY
at the Indium Corporation of America means purity of metals, and strict adherence to specifications.

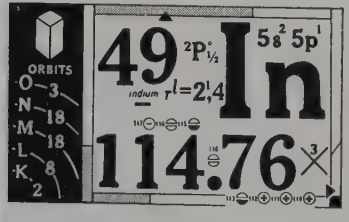
SERVICE
means prompt delivery to customers, and technical help in specific uses of Indium.

RESEARCH
means "forward looking" with respect to new products and new techniques.

Since 1934 when the Indium Corporation was formed and produced the first commercial amounts of Indium, we have gained in knowledge and in service to all the varied users of Indium in its almost limitless applications and forms.

Why not write us today . . . our years of research and experimentation, our pioneer developments, our experience in producing Indium to the exact specifications of our customers, our many technical helps are at your service.

Commercial quantities are available in Indium metal (specially refined 99.999% pure or 99.97% pure), Indium wire, foil, ribbon, pellets, spheres or powders. Also "Indalloy" intermediate solders and other high purity metals.



Write to Dept. S-759 for Indium booklet: "INDALLOY" Intermediate Solders."

THE INDIUM CORPORATION OF AMERICA

1676 Lincoln Avenue • Utica, New York

Since 1934 . . . Pioneers in the Development and Applications of Indium for Industry.

Circle No. 35 on Reader Service Card

P. Marshall, president of Western Union, describe some of the new electrical wonders that are now being developed and to salute the American Institute of Electrical Engineers. The occasion was the commemoration of the Institute's founding meeting which took place 75 years ago on May 13, 1884. The luncheon was one of many such affairs held throughout the country by the institute's 117 Sections to mark the Diamond Jubilee Year. AIEE, whose 1884 roster listed 71 members, among them such notables as Thomas Edison and Alexander Graham Bell, is now a world-wide organization with a membership exceeding 52,000.

Formation of Networks Infrared Science Laboratories for study and evaluation of advanced infrared systems has been announced by President M. D. Patrichi of Networks Electronic Corporation, manufacturers of miniaturized precision electronic components. Under the direction of Mr. Patrichi the laboratory will investigate infrared detection optical systems and applicable electronic devices. He also announced formation of a special engineering project group under the direction of Dr. Siegfried Lindena to design and develop a high power static inversion device with regulation, stability and reliability specifications superior to those now attainable. Dr. Lindena is the first of several European scientists expected to join Networks under a long-range program designed to complement the company's technical operations with representatives of scientific thought from abroad.

Accurate Specialties Co., Inc., Woodside, N.Y. has leased a 14,000 square foot plant at 338 Hudson Street, Hackensack, New Jersey, as a part of a planned expansion of production and research facilities for manufacturing high purity ultra-precise semiconductor preforms and components, it was announced by Mr. Nate Zimmer, President. In addition to production facilities the plant will include an analytical and research laboratory, which will be used to investigate new high purity semiconductor alloys and processes. This fourth expansion in 3 years will represent a 200% increase in productive capacity for manufacture of high purity ultra-precise semiconductor alloys and preforms used in making alloy junctions in transistors, diodes, rectifiers and similar devices.

Transistor diodes, tiny circuits within themselves, are spearheading an important new advance in electronics, declared Dr. William Shockley, co-inventor of the transistor, in an opening lecture May 21 at the International Convention on Transistors and Associated Semiconductor Products in London, England. Four-layer transistor diodes are the first commercially available examples of solid state circuitry, the noted scientist told the convention. They can be used to replace more complex transistor circuitry, saving space and weight, or to replace relays or switches by eliminating moving parts in applications of transistor diodes ranging from household electrical appliances to computers and missile control systems, he said. Recent experiments indicate that within two to three years transistor diodes will attain power levels from 10 to 100 times higher than related transistors with comparable frequencies and efficiencies, Dr. Shockley predicted.

Raytheon Company will be the new name of the electronics firm formerly known as Raytheon Manufacturing Company, officials announced recently. The change, voted by stockholders at the annual meeting, became effective May 4, 1959. The new name reflects the broadened activity of the Company which runs the gamut from basic research to field maintenance of intricate military systems. The Raytheon name was adapted in 1925. Prior to that time,

the firm was known as the American Appliance Company which was formed in 1922.

International Rectifier Corporation of El Segundo, California, has announced the formation of International Rectifier of Canada Ltd., to supply Canadian industry with a full complement of electronic-electrical components. Eric Lidow, President, said headquarters for the Canadian operation have been established at 1581 Bank Street in Ottawa, Ontario, with Earl F. Johnson as secretary-manager. International Rectifier expects to supply Canadian industry with diodes and rectifiers employing the semiconductive materials selenium, germanium and silicon, in addition to silicon solar cells and selenium self-generating photocells.

Allan Q. Mowatt, President of Atlas E-E Corporation announced the formation of Atlee Components Inc. The new company will be the West Coast manufacturing and sales subsidiary of the parent company, Atlas E-E Corporation. The increased sales and demands for services in the growing West Coast market necessitated the opening of a plant there, according to Mr. Mowatt. Atlee will manufacture the full line of the parent company's component holders and transistor clips. Mr. Mowatt stated that Atlee will have an extensive prototype facility to satisfy the new product needs of this area. The new company will be centrally located at 8220 Lankershim Blvd., North Hollywood, California and will be under the general managership of Clyde Rush, who is Vice-President of Atlee Components Inc.

A new Texas Instruments Incorporated plant at Dallas has been spotlighted as one of the ten top plants built in the United States in 1958. The 310,000-square-foot building houses the TI Semiconductor-Components division and is the world's largest facility for manufacturing transistors and related semiconductor devices. The plant was dedicated in June, 1958, and seven months later in January, 1959, construction started on a 192,000-square-foot addition to it. TI's unusual plant was picked from more than 700 nationwide entries in the 25th annual "Top Plants" competition. The two-story structure of unusual design is located on a 300-acre site 11 miles from downtown Dallas on the city's principal expressway. It is the first of a number of buildings planned for the site to serve research, manufacturing and administrative functions. A new 87,500-square-foot Central Research Laboratory building is under construction there and will be opened this summer.

Acoustica Associates, Inc. has acquired the Universal Dynamics Corporation, Santa Barbara, California, manufacturers of piezoelectric ceramics used in ultrasonic and sonar equipment, it was announced by Robert L. Rod, President of Acoustica, one of the country's largest manufacturers of ultrasonic equipment. Universal will operate as a subsidiary and its new facilities contain the most modern production equipment permitting high volume output for quick delivery of not only standard piezoelectric ceramics but also special large and odd-shape ceramic pieces having Curie points as high as 300 degrees C. The plant contains a completely equipped electronic laboratory for testing finished ceramic materials. The growing applications in which such ceramic material is used include passive underwater listening systems and hydrophones, and active submarine-detection devices. High quality piezoelectric ceramics are also being used in expanding quantities as the key elements of ultrasonic systems for processing various chemicals and liquids, for ultrasonic cleaning, and for gauging liquid levels through the use of these high frequency sound waves.

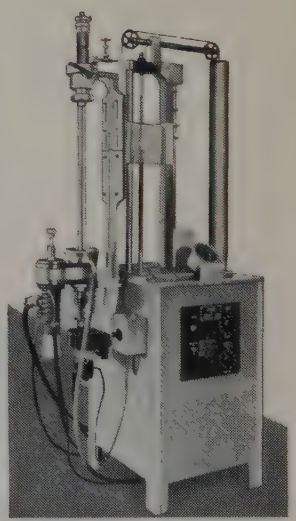
The Lepel line of induction heating equipment represents the most advanced thought in the field of electronics as well as the most practical and efficient source of heat yet developed for numerous industrial applications.
If you are interested in induction heating you are invited to send samples of the work with specifications. Our engineers will process and return the completed job with full data and recommendations without any cost or obligations.

FLOATING ZONE FIXTURE FOR METAL REFINING AND CRYSTAL GROWING

A new floating zone fixture for the production of ultra-high purity metals and semi-conductor materials. Purification or crystal growing is achieved by traversing a narrow molten zone along the length of the process bar while it is being supported vertically in vacuum or inert gas. Designed primarily for production purposes, Model HCP also provides great flexibility for laboratory studies.

Features

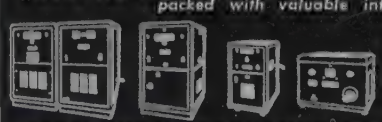
- A smooth, positive mechanical drive system with continuously variable up, down and rotational speeds, all independently controlled.
- An arrangement to rapidly center the process bar within a straight walled quartz tube supported between gas-tight, water-cooled end plates. Placement of the quartz tube is rather simple and adapters can be used to accomodate larger diameter tubes for larger process bars.
- Continuous water cooling for the outside of the quartz tube during operation.
- Assembly and dis-assemby of this system including removal of the completed process bar is simple and rapid.



Model HCP

Electronic Tube Generators from 1 kw to 100 kw.
Spark Gap Converters from 2 kw to 30 kw.

WRITE FOR THE NEW LEPEL CATALOG . . . 36 illustrated pages packed with valuable information.



All Lepel equipment is certified to comply with the requirements of the Federal Communications Commission.

LEPEL HIGH FREQUENCY LABORATORIES, INC.
55th STREET and 37th AVENUE, WOODSIDE 77, NEW YORK CITY, N. Y.

Circle No. 16 on Reader Service Card

CHARACTERISTICS CHART of NEW TRANSISTORS

Announced Between January 1, 1959 and February 28, 1959

MANUFACTURERS (In Order of Code Letters)

ARA— Advanced Research Associates, Inc.
AMP— Amperex Electronic Corp.
BEN— Bendix Aviation Corp.
BOG— Bogue Electric Mfg. Co.
BTHB— British Thomson-Houston Export Co., Ltd.
CBS— CBS-Electronics
CTP— Clevite Transistor Products, Inc.
DEL— Delco Radio Div., General Motors Corp.
EEVB— English Electric Valve Co., Ltd.
ESEB— Edison Swan Electric Co., Ltd.
FCS— Fairchild Semiconductor Corp.
FTHF— French Thomson-Houston Semiconductor Dept.
GECB— General Electric Co., Ltd.
GE— General Electric Co.
GEM— Great Eastern Mfg. Co.
GTC— General Transistor Corp.
HUG— Hughes Aircraft Co.
HIVB— Hivac Ltd.
IND— Industro Transistor Corp.
LCTF— Labortoire Central de Telecommunications
MIN— Minneapolis-Honeywell Regulator Co.
MOT— Motorola, Inc.
MUL— Mullard Ltd.
NTLB— Newmarket Transistors Ltd.
NPC— Nucleonics Products Co.
PSI— Pacific Semiconductors, Inc.
PHI— Philco Corp., Landsdale Tube Co.
RAY— Raytheon Co.
RCA— Radio Corp. of America, Semiconductor Div.
SIE— Siemens & Halske Aktiengesellschaft
SONY— Sony Corp.
SPE— Sperry Gyroscope Co.
SPR— Sprague Electric Co.
SYL— Sylvania Electric Products Inc.
STCB— Standard Telephone & Cables, Ltd.
TKAD— Suddeutsche Telefon-Apparate-, Kabel und Drahtwerke
TRA— Transitron Electronic Corp.
TFKG— Telefunken Ltd.
TI— Texas Instruments
TUN— Tung-Sol Electric, Inc.
WEC— Western Electric Co., Inc.
WEST— Westinghouse Electric Corp.

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. (See code at start of charts)
				P_C (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
2N255A	3	PNPA	Ge	25W	2.5	15	15		PG at 2.0W	35	CBS
2N256A	3	PNPA	Ge	25W	2.5	25	25		PG at 2.0W	35	CBS
2N511	3	PNP	Ge	80W		40			h_{FE}: 10A	10 min	TI
2N511A	3	PNP	Ge	80W		60			h_{FE}: 10A	10 min	TI
2N511B	3	PNP	Ge	80W		80			h_{FE}: 10A	10 min	TI
2N512	3	PNP	Ge	80W		40			h_{FE}: 15A	10 min	TI
2N512A	3	PNP	Ge	80W		60			h_{FE}: 15A	10 min	TI
2N512B	3	PNP	Ge	80W		80			h_{FE}: 15A	10 min	TI
2N513	3	PNP	Ge	80W		40			h_{FE}: 20A	10 min	TI
2N513A	3	PNP	Ge	80W		60			h_{FE}: 20A	10 min	TI
2N513B	3	PNP	Ge	80W		80			h_{FE}: 20A	10 min	TI
2N514	3	PNP	Ge	80W		40			h_{FE}: 25A	10 min	TI
2N514A	3	PNP	Ge	80W		60			h_{FE}: 25A	10 min	TI
2N514B	3	PNP	Ge	80W		80			h_{FE}: 25A	10 min	TI
2N649	2	NPNA	Ge	100		20	18		h_{FE}: I_C- 50ma	65	RCA
2N701	4	PNPD	Ge	75	1000	30	25		h_{FE}: 2ma, 200Mc	6.5	MOT
2N702	2,5	NPND	Si	500		20		100	h_{FE}: I_C- 10ma	30	TI
2N705	2,5	PNPD	Ge	150	500	15	15	250	h_{fe}	25	TI
2N1093	2,5	PNPA	Ge	150		30		8.0	h_{fe}	50	TI
2N1131	3,4,5	PNPD	Si	2.0W	75	40	30	80	CE at 30 Mc	11 db	FSC

NOTATIONS

Under Use

1 - Low power a-f equal to or less than 50 mw
2 - Medium power a-f > 50 mw and equal to or less than 500 mw
3 - Power > 500 mw
4 - r-f/i-f
5 - Switching and Computer
⍁ - Revised Spec.

Under Type

A - Alloyed
D - Diffused or Drift
G - Grown
H - Hook Collector
M - Microalloy
O - Other
S - Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
§ - Tetrode

Under f_{ab}

* Maximum Frequency
# Figure of Merit
△ $f_{\alpha e}$
ø Minimum
† Gain Bandwidth Product $h_{fe} \times f_{hfe}$

PHILCO

Silicon Surface Alloy Transistors

For Reliable Performance at High Temperatures

These field proven Philco Silicon Transistors (SAT*) permit complete transistorization of military and commercial circuits that are subjected to high ambient temperatures . . . with excellent performance at junction temperatures ranging from —65° C to +140° C.

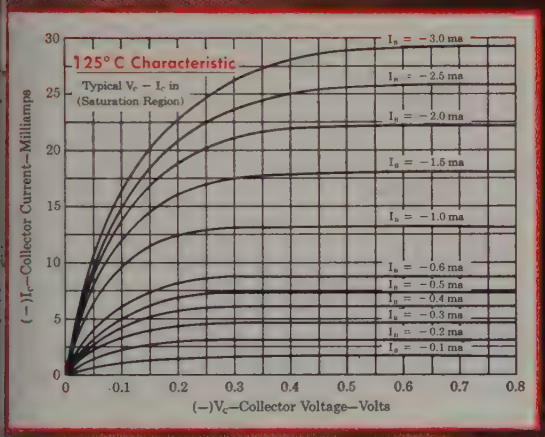
Type 2N495 is a general purpose silicon transistor designed for amplifier and oscillator applications at frequencies through 15 mc.

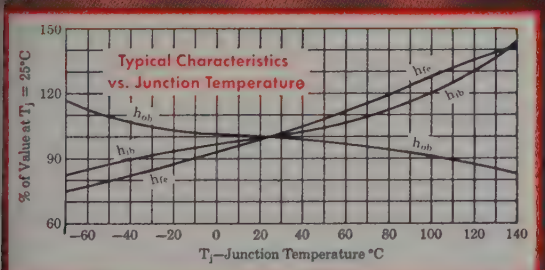
Type 2N496 is specifically engineered for high speed switching circuits. The frequency at which beta equals unity (f_t) is typically 18 mc. It gives the designer the advantages of low saturation resistance and low voltage operation, at high junction temperatures.

These units are environmentally tested in accordance with MIL-T-19500A.

Complete information will be supplied upon request. Write Lansdale Tube Company, Division of Philco Corporation, Lansdale, Pa., Dept. SC-759.

**Trade Mark Philco Corp. for Surface Alloy Transistor*





CHARACTERISTICS OF TYPES 2N495 and 2N496

CHARACTERISTIC	CONDITION	TYPICAL VALUE 2N495	TYPICAL VALUE 2N496
Current Amplification Factor, h_{fe}	$V_{CE} = -6$ v, $I_E = 1$ ma	20	
Current Amplification Factor, h_{FE}	$V_{CE} = -0.5$ v, $I_C = -15$ ma		16
Output Capacitance, C_{ob}	$V_{CB} = -6$ v, $I_E = 1$ ma	7 μμf	7 μμf
Maximum Frequency of Oscillation, f_{os} max.	$V_{CB} = -6$ v, $I_E = 1$ ma	21 mc	
Frequency for Beta = 1, f_t*	$V_{CE} = -6$ v, $I_E = 1$ ma, f = 4 mc		18 mc
Cutoff Current, I_{CBO} or I_{EBO}	V_{CB} or $V_{EB} = -10$ v	.001 μa	.001 μa

Maximum Power Dissipation—150 mw

Maximum Collector Voltage 2N495—25 V
2N496—10 V

*f_t (the frequency at which beta is unity) is typically 85% of the alpha cutoff frequency.

Immediately available in quantities 1 to 99 from your Philco Industrial Semiconductor Distributor

PHILCO

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

Circle No. 17 on Reader Service Card

CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P_C (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
2N1132	3,4.5	PNPD	Si	2.0W	75	40	30	80	CE at 30 Mc	12 db	FSC
2N1139	5		Si	500		15	15	t_r-12 musec	h_{FE}:I_C- 10ma	40	TRA
2N1167	3	PNPA	Ge	50W	1.2	100	80	4KcΔ	h_{FE}: 25A	25	MOT
2N1172	2	PNPA	Ge	4.0W	15	40	20	17KcΔ	h_{FE}:I_C-500ma	30	DEL
2N1176	2	PNP	Ge	300	200	20	20		h_{fe}:I_c- 10ma	20 min	BEN
2N1176A	2	PNP	Ge	300	200	40	40		h_{fe}:I_c- 10ma	20 min	BEN
2N1176B	2	PNP	Ge	300	200	60	60		h_{fe}:I_c- 10ma	20 min	BEN
2N1219	5	PNPA	Si	150	830	30	25	7.0	h_{FE}:I_C- 5ma	27	GTC
2N1220	5	PNPA	Si	150	830	30	25	3.5	h_{FE}:I_C- 5ma	14	GTC
2N1221	5	PNPA	Si	150	830	30	25	7.0	h_{fe}:I_e- 1ma	27	GTC
2N1222	5	PNPA	Si	150	830	30	25	3.5	h_{fe}:I_e- 1ma	14	GTC
2N1223	5	PNPA	Si	150	830	40	40	2.0	h_{fe}:I_e- 1ma	10	GTC
2N1228	2,5	PNPA	Si	250	550	15	15				HUG
2N1229	2,5	PNPA	Si	250	550	15	15				HUG
2N1230	2,5	PNPA	Si	250	550	35	35				HUG
2N1231	2,5	PNPA	Si	250	550	35	35				HUG
2N1232	2,5	PNPA	Si	250	550	65	65				HUG
2N1233	2,5	PNPA	Si	250	550	65	65				HUG
2N1234	2,5	PNPA	Si	250	550	110	110				HUG
2N1238	2,5	PNPA	Si	1.0W	27	15	15				HUG
2N1239	3,5	PNPA	Si	1.0W	27	15	15				HUG
2N1240	3,5	PNPA	Si	1.0W	27	35	35				HUG
2N1241	3,5	PNPA	Si	1.0W	27	35	35				HUG
2N1242	3,5	PNPA	Si	1.0W	27	65	65				HUG
2N1243	3,5	PNPA	Si	1.0W	27	65	65				HUG
2N1244	3,5	PNPA	Si	1.0W	27	110	110				HUG
2N1245	3	PNPA	Ge	.25W	2.5	25	25		h_{FE}:I_C- .5A	75	CBS
2N1246	3	PNPA	Ge	25W	2.5	25	25		h_{FE}:I_C- .5A	150	CBS
2N1251	2	NPNA	Ge	150	400	20	15	.60	PG at 1000cps	40 db	SYL
2N1261	3	PNPA	Ge	32W	2.2	60	45	.20Ø†	h_{FE}:I_C- 2A	30	MIN
2N1262	3	PNPA	Ge	32W	2.2	60	45	.20Ø†	h_{FE}:I_C- 2A	43	MIN
2N1263	3	PNPA	Ge	32W	2.2	60	45	.20Ø†	h_{FE}:I_C- 2A	64	MIN
2N1264	4	PNPD	Ge	50	1000	20		3.0Δ	PG at 1.5 Mc	15 db	SYL
2N1265	1	PNPA	Ge	50	1000	10		.60	PG at 1000cps	37 db	SYL
2N1266	4	PNPA	Ge	80	750	10	10	1.5Δ	PG at 455Kc	24 db	SYL
GET102	2	PNPA	Ge	200	200	30	20	1.5*	h_{fe}: 1ma	110	GECB
GET111	2	PNPA	Ge	200	200	60	20	1.5*	h_{fe}: 50ma	100	GECB
GET113	2	PNPA	Ge	200	200	15	15	1.5*	h_{fe}: 1ma	110	GECB
GT327A	2	PNPA	Si	150		50	40	.20	h_{fe}:I_e- 3ma	14	GTC
GT328A	2	PNPA	Si	150		50	35	.30	h_{fe}:I_e- 3ma	25	GTC
H200EA	3	PNPA§	Ge	63W	1.1	60	35	.60Ø†	h_{FE}:I_C- 5A	50	MIN
H200EB	3	PNPA§	Ge	63W	1.1	80	50	.30Ø†	h_{FE}:I_C- 5A	40	MIN
LT5163	3	NPNA	Ge	20W	3.0	60			h_{FE}:I_C- .5A	40	CBS
LT5163L	3	NPNA	Ge	20W	3.0	60	45		h_{FE}:I_C- .5A	40	CBS
LT5164	3	NPNA	Ge	20W	3.0	80			h_{FE}:I_C- .5A	40	CBS

NOTATIONS

Under Use

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3 - Power > 500 mw
4 - r-f/i-f
5 - Switching and Computer
Ø - Revised Spec.

Under Type

A - Alloyed
D - Diffused or Drift
G - Grown
H - Hook Collector
M - Microalloy
O - Other
S - Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
§ - Tetrode

Under f_{ab}

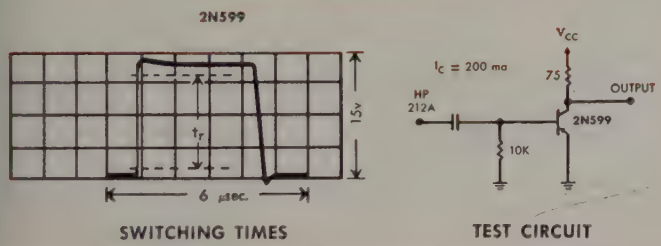
* Maximum Frequency
# Figure of Merit
Δ $f_{\alpha e}$
ø Minimum
† Gain Bandwidth Product $h_{fe} \times f_{hfe}$

Now...from PHILCO
A complete family of Medium Frequency Transistors

Type	Outline	Max. Readings			General Performance		"ON" Switch Performance	
		P_T mw	V_{CB} volts	I_C ma	Min. $f_{\alpha b}$ mc	Typical h_{FE} $V_{CE} = -1v, I_C = -100$ ma	Max. V_{CE}	Max. V_{BE}
2N597	TO-9	250	45	400	3	70	0.2	0.34
2N1123	TO-31	750*	45	400	3	70	0.2	0.34
2N598	TO-9	250	30	400	5	85	0.2	0.34
2N600	TO-31	750*	30	400	5	85	0.2	0.34
2N599	TO-9	250	30	400	12	105	0.2	0.34
2N601	TO-31	750*	30	400	12	105	0.2	0.34

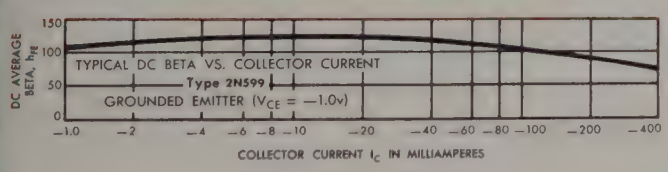
*Peak Dissipation at 25°C=1 Watt

TYPICAL RISE TIME CIRCUIT



SWITCHING TIMES — TEST CIRCUIT

TYPICAL DC BETA VS. COLLECTOR CURRENT



Make Philco your prime source for all transistor information and prices. Write Dept. SC-759

Circle No. 18 on Reader Service Card

- **High Dissipation: to 1 watt peak at 25°C**
- **High Current: Max. I_C = —400 ma**
- **High Temperature: 100° C Max.**
- **High Voltage: Max. V_{CB} to —45v**
- **High Frequencies: Min. $f_{\alpha b}$ to 12 mc**

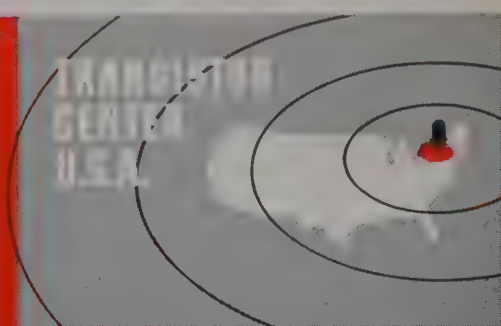
Philco's complete family of PNP germanium alloy junction transistors is available in both studded and unstudded cases (TO-31 and TO-9), permitting operation at power levels as high as 1 watt peak. They offer the designer complete flexibility, providing a choice within each form factor to meet circuit requirements for voltage, gain and frequency. These transistors feature a unique, patented, cold-welded *copper* housing and internal construction that result in lower junction temperatures at normal operating power levels. (K factor as low as 0.1° C/mw.) Their design insures improved life and reliability at temperatures as high as 100° C.

The high beta of these transistors at high current makes them particularly applicable to medium speed flip-flops, logic gates, drum writers and core-driver circuits. The 30v to 45v collector rating provides the high level logic swings required in many data processing equipments. The entire family is available in production quantities . . . and in quantities 1-99 from your local Philco Industrial Semiconductor Distributor.

PHILCO

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA



CHARACTERISTICS CHART of NEW TRANSISTORS

TYPE NO.	USE (See Code Below)	TYPE (See Code Below)	MAT	Max. Ratings @ 25° C				Typical Characteristics			MFR. See code at start of charts
				P_C (mw)	DERATING °C/W	V_{CB}	V_{CE}	$f_{\alpha\beta}$ (mc)	Gain PARAMETER and (condition)	Gain VALUE	
LT5164L	3	NPNA	Ge	20W	3.0	80	60		h_{FE}:I_C- .5A	40	CBS
LT5165	3	NPNA	Ge	20W	3.0	35			h_{FE}:I_C- .5A	40	CBS
LT5165L	3	NPNA	Ge	20W	3.0	35	30		h_{FE}:I_C- .5A	40	CBS
TK28B	2,5☑	PNPA	Ge	200	250	26	25	9.0	h_{FE}:I_C- 60ma	54	STCB
TK70A	2,4,5☑	NPNA	Si	325	380	30	20	5.5	h_{FE}:I_C-100ma	30	STCB
TK71A	2,4,5☑	NPNA	Si	325	380	30	25	2.0	h_{FE}:I_C-100ma	14	STCB
TK72A	2,4,5	NPNA	Si	325	380	15	12	1.2	h_{FE}:I_C- 10ma	18	STCB
V10/15	2,5	PNP	Ge	125	400	10		10	h_{fe}:500ma	40	NTLB
V10/25	2,5	PNP	Ge	125	400	10		5.0	h_{fe}:500ma	25	NTLB
V15/15NP	3	PNP	Ge	15W	1.0	15		.175	h_{fe}:200ma	25	NTLB
V15/20R	1,4	PNPD	Ge	25	2000	15		30	h_{fe}: 1ma	25	NTLB
V15/30NP	3	PNP	Ge	15W	1.0	15		.175	h_{fe}:200ma	40	NTLB
V30/15NP	3	PNP	Ge	15W	1.0	30		.175	h_{fe}:200ma	25	NTLB
V30/30NP	3	PNP	Ge	15W	1.0	30		.175	h_{fe}:200ma	40	NTLB

NOTATIONS

Under Use

1 - Low power a-f equal to or less than 50 mw
2 - Medium power a-f > 50 mw and equal to or less than 500 mw
3 - Power > 500 mw
4 - r-f/i-f
5 - Switching and Computer
☑ - Revised Spec.

Under Type

A - Alloyed
D - Diffused or Drift
G - Grown
H - Hook Collector
M - Microalloy
O - Other
S - Surface Barrier
UNI - Unijunction Transistor
Y - Symmetrical
§ - Tetrode

Under f_{ab}

* Maximum Frequency
# Figure of Merit
△ $f_{\alpha e}$
ø Minimum
† Gain Bandwidth Product $h_{fe} \times f_{hfe}$

The following manufacturers have announced that they have begun supplying the indicated previously registered transistors.

General Transistor: 2N388, 2N396, 2N495, 2N496
Motorola: 2N297A
Texas Instruments: 2N395, 2N396, 2N397

FROM PAGE 44

MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFICATION	DESCRIPTION	MFR.
1N26B	1,2	1N26 for 150C operation; Max. noise ratio-1.5	PHI
1N78C	1,2	1N78 for 150C operation; I.F. impedance 425-565ohms.	PHI
1N1838	1,2	Low flicker noise germanium mixer at R. F. frequencies below 14kMc.	PHI
HPA2800	Paramp diode	70 kMc. cut-off at 7V. breakdown; C'-0.1 uuf	HUG
HPA2810	Paramp diode	70 kMc. cut-off at 7V. breakdown; C'-0.2 uuf	HUG
MS1	5	Active Area, 0.187 in. x 0.100 in.	FERB
MS2	5	Active Area, 0.7 in. 0.5 in.	FERB
MS10	5	Active Area, 0.3 in. diameter	FERB
MS11	5	Active Area, 1.0 in. diameter	FERB
1N2175	Photo-Duo-Diode	.5ua. max Reverse I at 50V, Light I/Dark I-10,000max.	TI
OAP12	4	Germanium-50ma/lumen area-1sq. mm.	MUL
SERI	Solion-Duo-Diode	Readout integrator-.9V.max.,input 100ua.max., readout-1ma.max.	TEX

PHILCO Transistors operate

51,614,343

SERVICE HOURS*

in High-Speed Computer Circuits

with only 8 Failures!‡

Total Transistor Service Hours To Date	Total Transistors	Total Failures‡	Report
1,068,111	99	0	ELECTRONICS, Oct. 1, 1957, pg. 167
5,460,000	600	1	ELECTRONICS, Oct. 1, 1957, pg. 167
1,250,000	125	0	PHILCO REPORT, Feb. 10, 1959
16,000,000	10,192	2	WJCC REPORT, Feb. 1957
8,640,000	8,000	2	PHILCO REPORT, Feb. 12, 1959
19,196,232	18,601	3	PHILCO REPORT, Nov. 19, 1958

‡Failures due to all causes including human error.

Carefully documented reports now reveal that Philco electro-chemical transistors have amassed more than fifty-million hours of operation in six computers under actual field conditions. Here is proof of the outstanding performance and reliability that electronics engineers and designers have come to expect from Transistor Center, U.S.A. Of course, these transistors are still operating in their original high speed computer switching circuits . . . extending service life data on these transistors beyond the limits of any previously published information.

When you think of transistors, think first of Philco. Make Philco your prime source for all transistor information.

Write to Lansdale Tube Company, Division of Philco Corporation, Lansdale, Pa., Dept. SC 759

*Documented service hours in these six computers only. Total transistors hours in similar circuits are many times this amount.

Circle No. 19 on Reader Service Card

PHILCO CORPORATION

LANSDALE TUBE COMPANY DIVISION

LANSDALE, PENNSYLVANIA

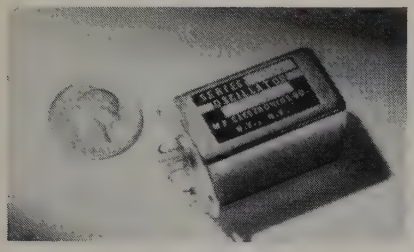
New Products

(from page 45)

Audio Tone Oscillators

The Series 101 and 102 Audio Tone Oscillators produced by MF Electronics, are completely self-contained assemblies which generate sine waves of rated accuracy upon application of the required DC potential. They operate from either 12 or 28 volts, specifically pointed towards use in portable and test set, as well as aircraft equipment. Series 102 generates 1 or 2 volts RMS with a frequency accuracy of ±2%. Series 101 generates 1 or 2 volts RMS with a frequency accuracy of ±5%. The accuracy specification is applicable over the range of ambient temperatures of −25 to +55°C.

Circle 75 on Reader Service Card



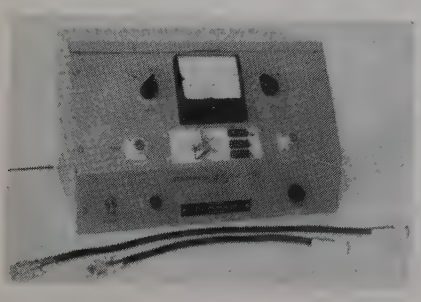
Silicon Solar Cell Batteries

High efficiency silicon solar battery modules, manufactured by International Rectifier Corporation, are designed for powering transistorized equipment during daylight operation, as well as for charging storage batteries for continuous day and night operation. The output voltage of the solar module is 1.75 volts at 30°C cell temperature, and 1.5 volts d.c. at 65°C. Each module contains five series-connected 1 cm. x 2 cm. solar cells embedded in an epoxy mold that provides a rugged, shock-resistant, weatherproof housing. Request Bulletin SR-276.

Circle 68 on Reader Service Card

Diode Test Set

Model ND-1 Standard Diode Pulse Recovery Test Set, is being manufactured by The Indikon Company. Used with a suitable square-wave generator and oscilloscope, it operates over the following ranges: forward bias current of 2 to 40 ma; inverse voltage 5 to 50 volts; load resistance 500 to 3000 ohms; load capacitance 10-100 μμf; inverse enhancement current 5 ma to 50 μA; measurement time interval one tenth to ten μsec. Built in test clips, interconnecting cables, and resistance and capacitance standards are provided.

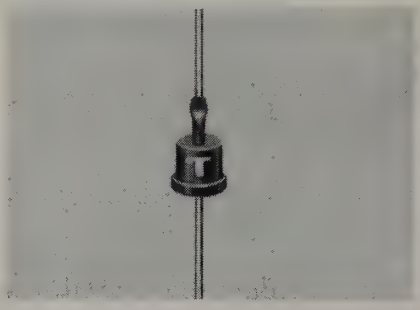


Circle 78 on Reader Service Card

Silicon Rectifiers

Transitron Electronic Corporation announces military approval of a series of axial lead silicon rectifiers. These JAN rectifiers are designed for use in applications that demand reliable operation at high temperatures and under severe environmental conditions. Types 1N538, 1N540, and IN547 offer high efficiency and ease of mounting in new and existing rectifier applications. Maximum ratings are 200v, 400v, and 600v respectively at 250 milliamps, 150 degrees centigrade ambient temperature.

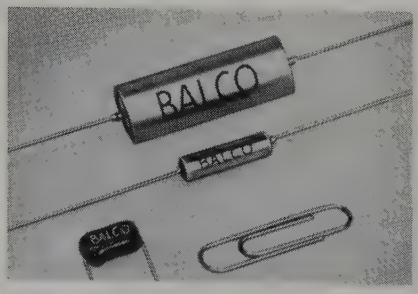
Circle 51 on Reader Service Card



Miniaturized Capacitors

The Capacitor Division of Balco Research Laboratories announces the development of a new series of low voltage, space saving capacitors for high temperature environments, transistor circuits and high performance applications. Known as the Balco LV and LZ Series, the new capacitors are normally designed for continuous operation from −70°C to 175°C without derating. Extended temperature types T_1 and T_2 are available to 200°C and 250°C respectively without derating. Available hermetically sealed or epoxy dipped and with axial, radial or dual leads.

Circle 73 on Reader Service Card



Coaxial Diodes

The 1N78B and reversed polarity 1N78BR coaxial microwave silicon mixer diodes are available from Microwave Associates. The new types are directly interchangeable with the 1N78A and 1N78AR respectively but offer improved noise figure for microwave receivers operating in the 12.4-18.0 kmc frequency range. Maximum conversion loss and noise temperature ratio is 6.5 db and 1.3 times respectively. Calculated maximum receiver noise figure at 16 kmc assuming a 1.5 db IF noise contribution is 8.8 db. Maximum VSWR limit is 1.6. IF impedance limits range between 365 to 565 ohms.

Circle 66 on Reader Service Card

Silicon Grown Ingots

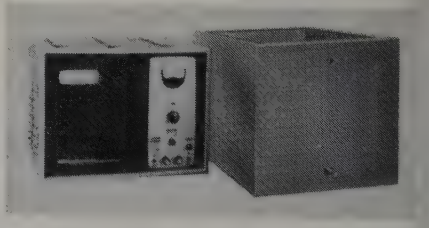
Individual grown silicon lenses to 10" diameter and silicon domes to 8" diameter for infrared use are now available in production and evaluation quantities according to an announcement by Knapic Electro-Physics, Inc. The principal use for this new large diameter material is in the manufacture of lenses for infrared sensing devices. Coated silicon lenses from this material will pass 92-97% of the infrared wave length band between 1 to 8.5 microns. Silicon lenses do not transmit visible light, and are used in infrared cameras, homing missiles, and early warning devices similar in application to present radar systems.

Circle 60 on Reader Service Card

Ultrasonic Cleaners

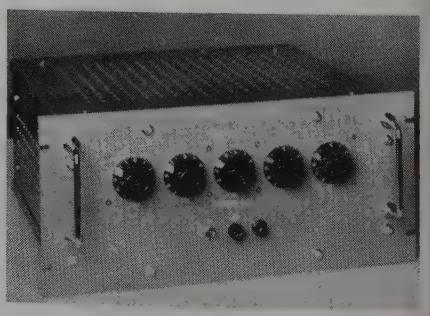
A new line of Multi-purpose Ultrasonic cleaners is now being manufactured by Circo Ultrasonic Corp. These high speed cleaners are ideal for hundreds of electronic applications including cleaning gears, bearings, instruments etc. Removing such things as excess solder flux, fingerprints, lint waxes, grease and polishing compounds from parts, has become a major use of Ultrasonic cleaning. Circosonic units consist of a generator and a matching transducerized tank.

Circle 74 on Reader Service Card



Current Governor

A programmable constant current source has been introduced by North Hills Electric Co. Designed especially for peak inverse voltage measurements, the CS-120 has a range of 0.1 μa to 10 ma. From 0-2200 V.D.C. Current is set to five



places by decade knobs arranged to provide a digital inline readout. Line and load regulation are better than 0.05%, with stability assured by a chopper stabilized feedback system. The current may be programmed or modulated by a remote signal.

Circle 62 on Reader Service Card

Zener Diodes

U. S. Semiconductor Products announces the development of a medium power double anode silicon zener diode

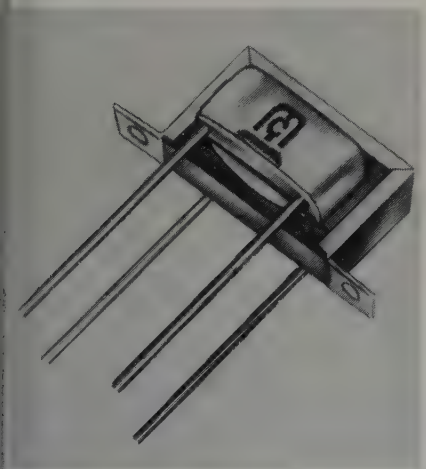
for clipping, pulse forming, and voltage regulating applications with lower T_C. Stainless cases measure only .290" long by .250" diameter, with choice of axial leads or stud mount. Zener voltages from 1½v to 35v and temperature coefficient from .038% to .066% per °C, together with abrupt breakdown, provide the flexibility needed for superior performance in commercial and military applications.

Circle 63 on Reader Service Card

Transistor Transformer

Microtran Company announces the addition of seven new micro-miniature transistor transformers to its catalog line. These new units are available in open frame construction with standard channel mounting or plug-in tab mounted channel. Size is approximately ¾" long by 7/16" high by ⅝" wide; approximate weight .4 oz.

Circle 71 on Reader Service Card



Silicon Rectifier Series

Magnetic amplifier and high voltage type silicon rectifiers produced by the double diffusion process have been released by Columbus Electronics. In hermetically sealed, axial lead, top hat design, magnetic amplifier types feature low leakage and low forward drop for use in circuits where extremely low reverse currents are of prime consideration. The high voltage types are also hermetically sealed and are available in the axial lead,

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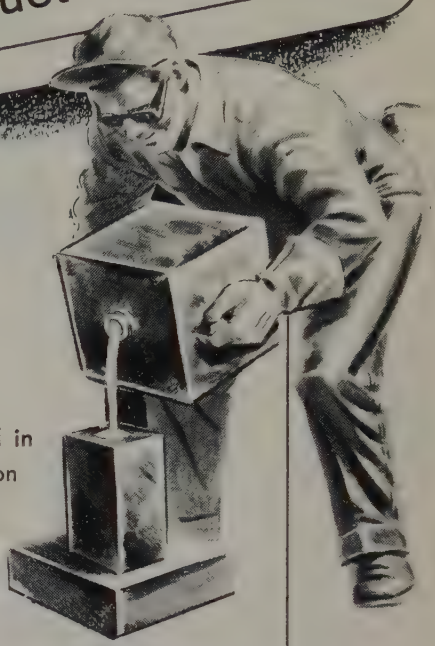

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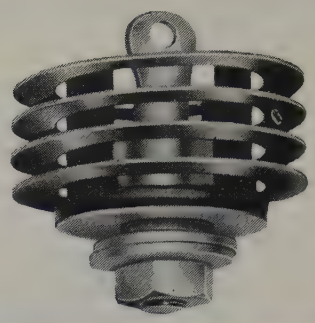

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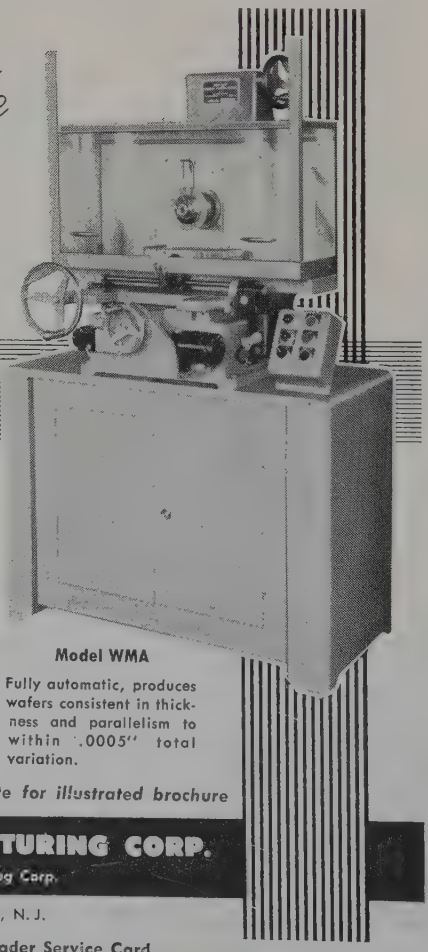

Micro-Matic Machines are used by

- ★ Audio Devices, Inc.
- ★ Bell Telephone Laboratories, Inc.
- ★ C.B.S.—Hytron
- ★ Clevite Transistor Products, Inc.
- ★ Federal Telecommunications Laboratories
- ★ General Electric Co.
- ★ International Business Machines Corp.
- ★ Radio Receptor Co., Inc.
- ★ Sperry-Rand Semi-Conductor Facilities
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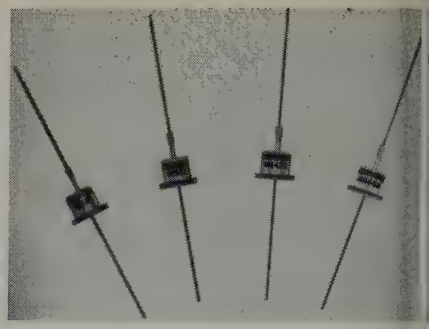


top hat design. Features include use for high voltage power supplies, high voltage blocking applications and clipping circuits.

Circle 67 on Reader Service Card

Frequency Shift Tone

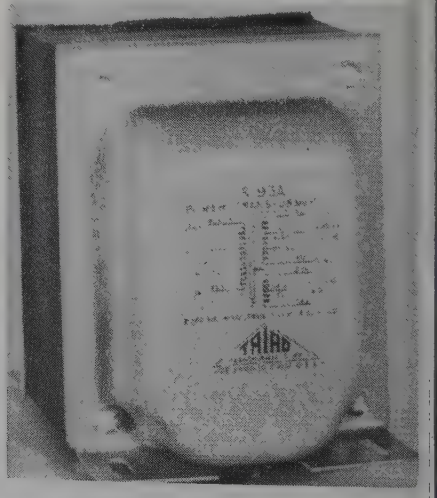
A new type of transistorized frequency shift powerline carrier tone equipment, designed to protect electric utility lines and transformers, is now being marketed by GE. Known as type 10 tone, the equipment operates from 24, 60 and 120 cell batteries and may be used over standard leased lines, private telephone lines, or carrier or microwave channels. High speed operation enables the trip coil of a circuit-breaker to be energized in only one cycle (60-cycle basis) for tripping signal transmission.

Circle 61 on Reader Service Card

Power Transformer

Development of voltage doubler circuits using silicon rectifier power supplies is now possible with the new Triad R-93A power transformer. It provides taps on both primary and secondary windings to allow several variations of output voltage, and is electrostatically shielded. Rated at 110/120 volts, 60 cps primary and 150/160/170 volts @ 500 ma secondary, the R-93A also supplies filament power of 6.3v-6A center tapped for hum reduction.

Circle 76 on Reader Service Card



udio Transistors

A new series of germanium general urpose PNP alloy junction audio transistors, types 2N1191, 2N1192 and 2N1193, available from Motorola Semiconductors. Maximum ratings are: Collector to ase Voltage, 40 Volts; Collector to mitter Voltage, 25 Volts; Collector Dispation @ 25°C Ambient, 175 milliwatts. urrent gain (h_{fe}) ranges are tightly ontrolled with 2.5:1 or less spread. Hermetically sealed.

Circle 64 on Reader Service Card

n-Line Rectifiers

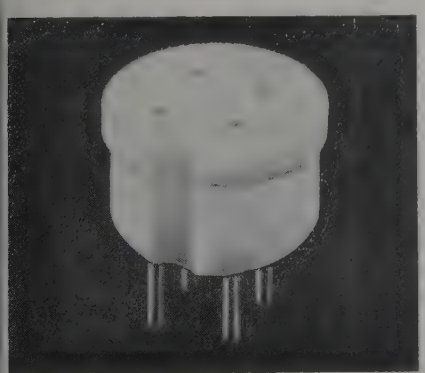
Availability of a complete line of inine ceramic-cased rectifiers was announced recently by Texas Instruments. The dense-alumina ceramic case proides 1.5-amp average rectified forward urrent at 50°C through efficient heat dispation. Voltage ratings are 200 to 600 v IV and the operating temperature range s from —65 to +150°C with current rating f 500 milliamps at 150°C.

Circle 53 on Reader Service Card

Subminiature Socket

A new four-contact sub-miniature tube socket and transistor socket has recently been marketed by Fluorocarbon Products Inc., a division of United States Gasket Company. Designated No. SJ-424, and designed especially for JETEC type sockets, the new space-saving socket features a Teflon body for compression mounting into a metal chassis and it requires no additional hardware.

Circle 72 on Reader Service Card



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New Literature

Up-to-date specifications on solid tantalum capacitors are presented in a revised engineering bulletin now available from Kemet Company, Division of Union Carbide Corporation. The four-page Electronics Products Engineering Bulletin No. 1 contains a general description of solid tantalum capacitors, a list of possible applications, and data on performance characteristics. A full-page table lists specifications such as capacitance, working voltage, weight, dimensions, and leakage current for 60 different solid tantalum capacitors made by Kemet Company.

Circle 122 on Reader Service Card

General Electric Communication Products Department has issued Bulletin GEA 6902 on transistorized frequency shift tone equipment for pilot relaying. The eight page bulletin describes basic equipment, such as transmitters, receivers, power supply, auxiliary units and tone frequencies used to perform transfer-trip, differential relaying and directional comparison relaying.

Circle 123 on Reader Service Card

A bulletin describing Acoustica Multipower transducers for ultrasonic applications is now available from Acoustica Associates, Inc. The characteristics of the new transducers, said to be considerably more efficient than conventional piezoelectric and magnetrostrictive types, are described in the new bulletin.

Circle 124 on Reader Service Card

Bulletin No. 721 describes and illustrates an integrated series of regulated transistorized power supplies. Specifications are given for over 40 different models manufactured by Electronics Measurements Company. Two categories are covered: wide range models and narrow range models. All models are for either rack or table mounting.

Circle 127 on Reader Service Card

Tenney Engineering has prepared an excellent brochure of general descriptive literature showing some of the many types of environmental test equipment they manufacture. The newest addition to the brochure covers high and low temperature chambers which they are offering for use in simultaneous tests with vibration exciters. Units are also available to perform altitude-temperature-vibration tests. Tenney will fully discuss all environmental problems for standard equipment as shown, or custom built chambers to specifications.

Circle 100 on Reader Service Card

Mucon Corporation announces catalog J-1, which describes in a four page brochure its complete line of subminiature ceramic capacitors made in twelve types of ceramic material. Axial and radial leads, ribbon leads, stand-off units, multiple units and various terminal arrangements are described. Stock high-capacitance units for transistor circuit application are also shown.

Circle 114 on Reader Service Card

High Temperature Ceramic Insulated Magnet Wire for service up to 1000° F. is the subject of a new 8-page brochure issued by Secon Metals Corporation. This new brochure contains the basic information on the original research performed approximately one year ago as well as the engineering data which was compiled during the past year. The brochure contains charts and diagrams to further amplify the data contained in it.

Circle 128 on Reader Service Card

Electronic Research Associates announces the availability of a new two-color catalog sheet covering data on their new Zener Voltage Tester Model DT100. This unit provides automatic readings of zener voltage as a function of current and is intended for both laboratory and factory measurement of zener diodes, transistor breakdown characteristics, semi-conductor rectifiers and similar solid state elements. The catalog sheet provides full descriptive material, specification data and prices.

Circle 129 on Reader Service Card

Telonic Industries, Inc., announce the availability of their new Short-Form Catalog, No. 8-A, covering Telonic Sweep Generators and allied equipment. The four page bulletin contains extensive information on the operation, construction, and features of Sweep Generators, Plug-in Markers, RF Filters, Detectors, and Attenuators. A convenient chart is included in the catalog listing all Sweep Generator models with their major performance specifications.

Circle 102 on Reader Service Card

Semicon, Incorporated has issued a brochure on their basic line of general purpose silicon rectifiers. Specifications of popular types are listed in this folder. Also included is some brief information about this new company as well as photographs showing a few of its activities.

Circle 105 on Reader Service Card

Cobehn, Inc., has issued a folder describing their High-Velocity Spray-Clean Technique and Equipment for electronic and instrument components and assemblies. Shown and described are automatic and manual precision parts cleaners and Spray-Clean Solvent. Cleans diodes, transistors, crystals, etc.

Circle 106 on Reader Service Card

Palmer Associates Inc., has issued a folder on their Glass-to-Metal Seals. Shown and described briefly are Condenser Seals, Multiple Headers, Transistor Mounts, Diode Closures, and Single Terminals. Also included is information on their research and development program as well as general information on the seals they manufacture.

Circle 107 on Reader Service Card

Sprague Electric has issued Engineering Bulletin #3205 on their Type 40D Extended-Life Miniature Tubular Aluminum Electrolytic Capacitors. Lists standard ratings, typical curves, and performance characteristics.

Circle 108 on Reader Service Card

Sylvania has announced publication of the second edition of its "Transistor Characteristics and Interchangeability Guide." The new booklet lists the characteristics and ratings of a wide variety of transistors used in entertainment, industrial, and military applications and, in addition, contains "a substitution chart and guide to manufacturers for close to 700 popular types," according to Ernest H. Ulm, general sales manager of Sylvania's Semiconductor Division. Including a glossary of transistor parameter symbols and definitions, the 20-page booklet lists mechanical specifications and connections for Sylvania's complete line of transistors and sockets.

Circle 111 on Reader Service Card

An 8-page catalog on Rectico Selenium Rectifiers contains basic characteristics in great detail with temperature derating table as well as an Overload and Allowable-Currents-under-Various-Forced-Cooling curves. One page is devoted exclusively to general design information on rectifier circuits. Current Ratings of cell sizes from 1" x 1" up to and including 6" x 12" are listed in a chart especially designed for ready reference. Also contains a Code Designation chart, a DC voltage chart and bracket dimensions in chart form.

Circle 118 on Reader Service Card

A highly useful four-page guide for buyers and engineers to assist them in the selection of GE Tantalytic Capacitors and Micro-Miniature Relaps has been prepared by Schweber Electronics. The guide lists Tantalytic Capacitors in numerical sequence by microfarads as well as an easy guide to the selection of micro-miniature Relays in five short steps and includes legend, case sizes and tolerances.

Circle 119 on Reader Service Card

A new technical bulletin describing the P Series miniature encapsulated pulse transformers, designed especially for printed circuit and automatic assembly applications, has been published by Technitrol Engineering Company. The P Series transformers are wound on high permeability ferromagnetic cores, resulting in a transformer design with a high pulse-width to rise-time ratio. The units are available in a number of case styles with a range of pulse widths from 0.05 to 10 microseconds for either vacuum tube or transistor applications.

Circle 120 on Reader Service Card

Literature on the recently-announced Rex-Array photorectifier plate now is available from the Electronics Components Division of Rex Corp. The literature gives basic information on the Rex-Array, which greatly extends the range and increases the flexibility of digital computer systems by behaving essentially like a diode array, but requiring practically no soldering and utilizing only approximately one-twentieth the space of diode arrays.

Circle 121 on Reader Service Card

A new and completely revised Transistor Interchangeability Guide was announced recently by the Raytheon Industrial Products Dept.

The guide opens to a 19 x 25 wall chart and provides Raytheon equivalents for over 200 EIA registered transistor types. Included are typical applications, outline drawings and heat radiator requirements.

Circle 112 on Reader Service Card

NEW

ZENER VOLTAGE TESTER*

Provides Automatic Presentation Of: zener diode voltage . . . transistor breakdown and zener voltage . . . diode inverse and reverse voltages. Also Tests For . . . zener diode impedance.

APPLICATIONS:

- *Laboratory Experimentation*
- *Circuit Design*
- *Quality Control*
- *Trouble Shooting*
- *Production Testing*

ERA's new Zener Diode Tester, Model DT100 is a self contained AC operated instrument designed for direct reading of zener voltage as a function of diode current. Provisions are also included for AC modulation of the diode current to permit the determination of zener impedance or zener slope for any given value of diode current. The instrument incorporates a wide range adjustable constant current generator which injects the desired value of current into the diode under test and maintains this current constant independent of line voltage fluctuations or zener voltage and impedance. The voltage appearing across the non-linear diode impedance is read directly by a high impedance DC voltmeter for the given current setting.

SPECIFICATIONS

Input Source	*115VAC, 60cps*
Zener Voltage Range	*0-300VDC*
Zener Current Range	*50 Microamperes-50ma*
Measurement Accuracy	*Better Than 2%*
Metering	*Direct Reading Ez, Iz*
Zener Impedance	*Provision for AC Modulation Iac, Eac Reading*
Physical	*Sloping Front Cabinet, Size: 12 x 8 x 19 inches*

Model DT100 **$275.00**

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ERA manufactures a full line of transistor test equipment and transistorized devices. Write for complete technical bulletin on this (Catalogue #115) and related devices.

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Circle No. 25 on Reader Service Card

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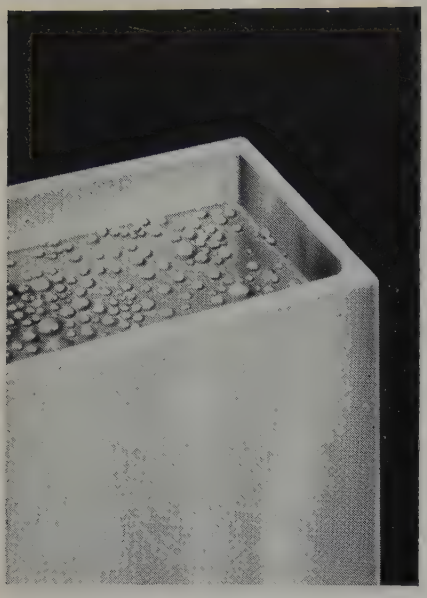

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Circle No. 26 on Reader Service Card

PERSONNEL NOTES

Appointment of Edward O. Johnson as Manager, High Temperature Product Development, RCA Semiconductor and Materials Division, was announced recently. Mr. Johnson will be responsible for administering high temperature materials programs of RCA at both the Somerville plant and RCA Laboratories at the David Sarnoff Research Center in Princeton, N. J. He will report to D. H. Wamsley, Manager, Semiconductor Engineering. He received a B. S. Degree in electrical engineering from Pratt Institute and has pursued graduate studies at Princeton University and the Swiss Federal Institute of Technology in Zurich.

Appointment of Dr. Robert B. Green as Manager, Materials Planning, Marketing Department, RCA Semiconductor and Materials Division was announced by Frank F. Neuner, Manager of the Department. Dr. Green is a graduate of Princeton University. He received Masters and Doctorate degrees from M.I.T. Dr. Green is a Fellow of the American Association for the Advancement of Science, a member of the American Physical Society, Intute of Metals (London), American Institute of Mining, Metallurgical and Petroleum Engineers, American Society of Metals, New York Metal Science Club and Phi Beta Kappa. He is also the author of several technical papers.

William S. Wheeler, General Manager of Motorola's Chicago Military Electronics Center, has been named a Vice President of the corporation and placed in charge of the company's total Military Electronics Division embracing activities in Chicago, Phoenix and Riverside, California. The Military Electronics Division continues in the general cognizance of Dr. Daniel E. Noble, Executive Vice President, along with the company's Semiconductor Products Division, and the Communications and Industrial Electronics Division. To succeed Mr. Wheeler, the company named Roy H. Olson, who has been Manager of the company's Microwave Department. Irving Koss, formerly Director of Marketing in the company's Communications and Industrial Electronics Division, has been appointed to succeed Mr. Olson.

The promotion of Richard C. Tonner as manufacturing superintendent of the semiconductor plant of Sylvania Electric Products at Woburn, Mass., has been announced. Mr. Tonner, who joined Sylvania in 1948 as a metallurgist, has been a section head at the Woburn plant since 1957. He attended Massachusetts Institute of Technology where he received a bachelor of science degree in metallurgy in 1948. He is a member of the American Society of Metallurgists and the American Institute of Metallurgical Engineers.

The announcement of John Clarke to the position of manager of applications engineering was made by Silicon Transistor Corp. Mr. Clarke comes from General Instrument Corp. where he was Chief Semiconductor Applications Engineer. He attended Polytechnic Institute of Brooklyn and in London, England, he was enrolled at Northampton Polytechnic Institute and Kingston College.

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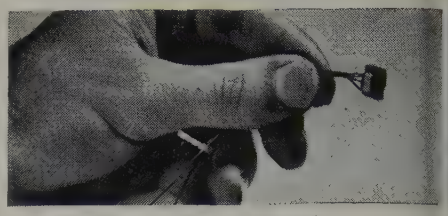
transformers
For transistor circuitry
in servo-mechanisms, hearing aids, radios, telephones



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M-200	.237	.340	.280
F-2010	.263	.410	.325
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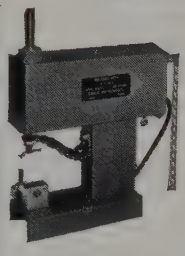

- **Precision Bench Welding Heads**
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- **NEW: Subminiature Precision Head WHD 5A and inexpensive, small Stored Energy Power Supply.**

Submit parts for free sample welds and ask for data sheet.

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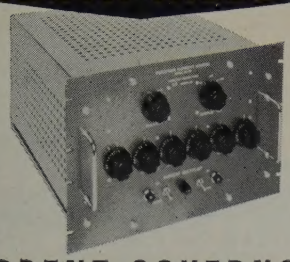
Circle 28 on Reader Service Card

The promotion of Frederick G. Plett as manufacturing superintendent of the semiconductor plant of Sylvania at Hillsboro, N. H., has been announced by Elmer J. Perry, general manufacturing manager of the company's Semiconductor Division. Mr. Plett has been supervisor of industrial engineering at Hillsboro since the opening of the plant in 1956. Prior to that, he was a senior industrial engineer at Woburn. He joined Sylvania as an industrial engineer at Boston in 1951. Mr. Plett attended Northeastern University where he received a bachelor of science degree in industrial engineering in 1951.

NORTH HILLS'



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Appointment of Arno Nash as Vice President and General Manager of the Radio Receptor Selenium Division of General Instrument Corporation was announced by Board Chairman Martin H. Benedek. Mr. Nash is a specialist in the selenium semi-conductor field. A graduate of Cornell University (Bachelor of Electrical Engineering, 1949), Mr. Nash also studied at New York University and the University of Missouri, and did post-graduate engineering work at Rutgers University.

Appointment of Robert R. Warriner as military applications specialist has been announced by Carroll G. Killen, manager of Field Engineering for Sprague Electric. Mr. Warriner comes to Sprague from the Aerovox Corp. of New Bedford, Mass. where he was chief applications engineer for the past 10 years. A graduate of the South Dakota State School of Mines and Technology, Mr. Warriner is a registered professional engineer and a senior member of the Institute of Radio Engineers.

North Hills Electric Co., Inc., Mineola, L.I., announces the appointment of Philip R. Geffe as Chief Filter Engineer. Mr. Geffe, who was Chief Filter Engineer at Triad Transformer Corp. and Director of Engineering at Hycor, is the author of several papers on network synthesis and advanced filter design.

A. J. Romano has been appointed sales manager of the Rectifier Division, Audio Devices, Inc., Santa Ana, Calif., according to an announcement from A. H. Bodge, vice-president and general manager of the Division. A graduate of the Massachusetts Institute of Technology, Mr. Romano has been associated with the electronics industry since 1942. His background includes engineering assignments involving magnetron development at Raytheon; guidance research engineering activities at Northrop in connection with the development of the Snark missile.

Glen H. Ockenhouse has been named plant metallurgist of Johnston & Funk Metallurgical Corporation, Wooster, Ohio, company president, Edward R. Funk announced recently. He will supervise the activities of the company's vacuum melting department, quality control and development laboratory. Prior to this, he was a melt shop metallurgist with Vacuum Metals Corporation, a division of The Crucible Steel Company of America. He is a 1953 graduate of Penn State University.

The Board of Directors, National Ultrasonic Corporation, 111 Montgomery Ave., Irvington, New Jersey, has elected L. R. Jeffrey, Jr., president and general manager. Mr. Jeffrey is a graduate of Williams College and Harvard Business School. Formerly he served as Vice President of Alcar Instruments, Inc.

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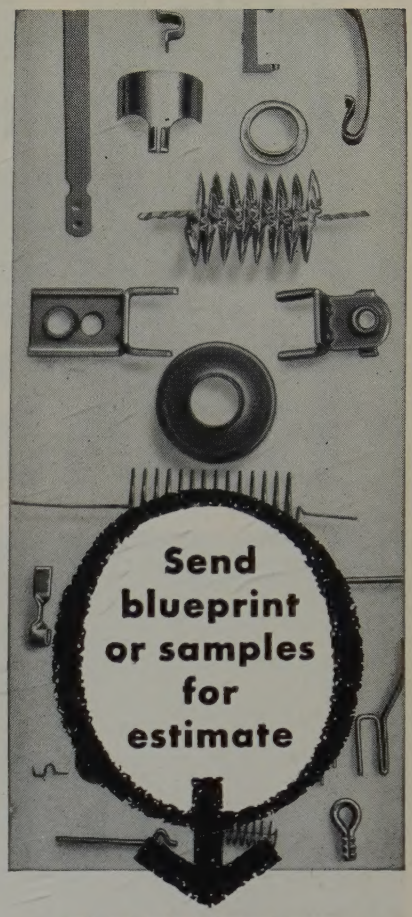

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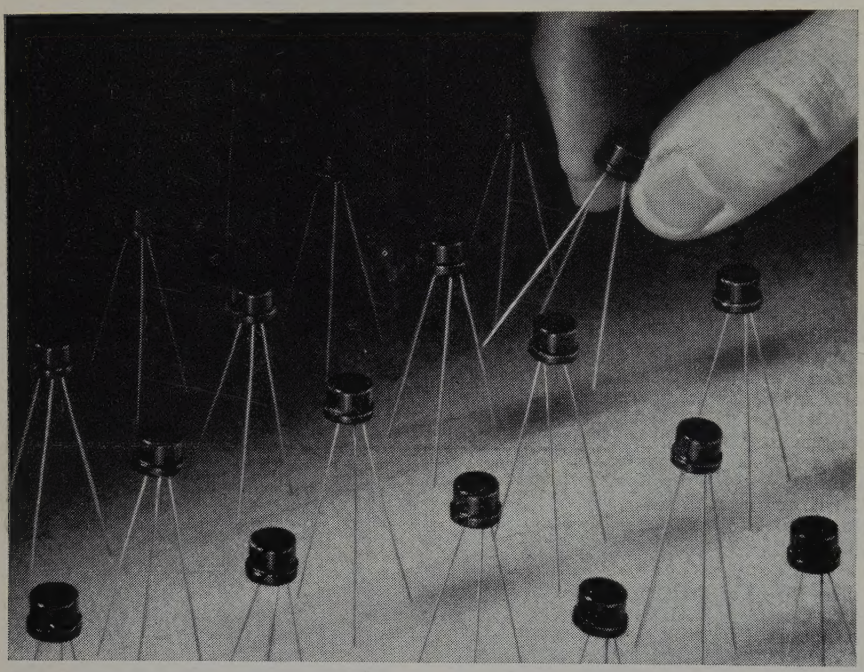
NEW BENDIX DRIVER TRANSISTORS



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Slated to be the "workhorse of the transistor industry", this new Bendix series consists of three models—each with a different voltage rating and each in high-volume production.

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Eliminating the internal connection between transistor and case allows circuit isolation. Long life and stable operation are assured by welded construction and a vacuum-tight seal.

ABSOLUTE MAXIMUM RATINGS

	Vce Vdc	Ic mAdc	Pc mW	Ib mAdc	T Storage °C	Tj °C
2N1008	−20	300	400	30	−65 to +85	85
2N1008A	−40	300	400	30	−65 to +85	85
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Circle No. 32 on Reader Service Card

Index to Advertisers

Acoustica Assocs., Inc. 62
Allegheny Electronic Chemical Co. 14
Allied Chemical Corp. General Chemical Div. 11
Art Wire & Stamping Co. 63

Baird-Atomic Inc. 47
Bendix Aviation Corp. 64
Birtcher Corporation, The 58

Cohn, Sigmund, Corp. 57
Columbus Electronics 46
Connecticut Instrument Corp. .. 47

Electronics Measurements Co., Inc. 4
Electronic Research Assoc. 61
Epoxy Products, Inc. 1
Ewald Instruments 62

General Electric Co., Heavy Military Elec. Dept. 6
Semiconductor Dtv. 59
Grace Electronic Chemicals, Inc. 9

Hoffman Electronics Semiconductor Division 5

Indium Corp. of America, The ... 48

Knapic Electro-Physics, Inc. 10
Kahle Engineering Co. 12
Kessler, Frank Co., Inc. 62

Lepel High Frequency Labs., Inc. 49

Merck & Co., Inc. 7
Micromech Manufacturing Corp. 58
Milgray ..... Covers IIA & IIB
Missile Manual and Guide 8

North Hills Electric Co., Inc. 63

Philco Corp., Lansdale Tube Co., Div. 51, 53, 55

Radio Corporation of America ... 60
Raytheon Manufacturing Co., Semiconductor Div. 2

Sarkes Tarzian, Inc. ..... Cover III
Schweber Electronics 63
Sprague Electric Co. ..... Cover IV

Texas Instruments, Inc. ... Cover II

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			55°C	100°C	150°C	55°C	100°C	150°C	55°C	100°C	150°C	55°C	100°C	150°C
10H	100	35	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	75	75	35
20H	200	70	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	75	75	35
30H	300	105	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	75	75	35
40H	400	140	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	75	75	35
50H	500	175	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	75	75	35
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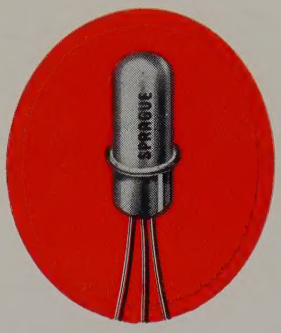

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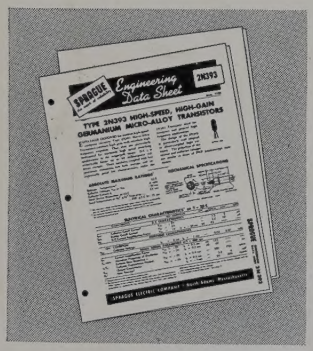

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